Division of Planning Research on-Call Task#7 - Evaluation of the Palmiter Method for Erosion Control and Stream Management

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The Palmiter method is a sustainable approach for managing stream bank erosion issues that emphasizes the use of on-site woody materials to direct the stream's energy away from problematic erosion areas. The purpose of this research was to determine if the method could be adopted by ODOT. Researchers evaluated existing Palmiter installations at several locations in Ohio and analyzed the stages of the project life cycle to identify project planning, regulatory, construction, and maintenance requirements necessary for ODOT to carry out a Palmiter method project using in-house resources. The conclusion of this study is that the Palmiter method is feasible as a cost-effective and sustainable option for ODOT's erosion control and stream management project needs, and that Palmiter method projects can be implemented using in-house personnel with expert assistance and/or training on the method.		
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PROBLEM STATEMENT

The Ohio Department of Transportation (ODOT) carries out routine maintenance of stream crossings along embankments, culverts, and bridges to ensure that bank erosion and river channel migration issues do not adversely affect the Department's infrastructure. Stream restoration and maintenance techniques used by ODOT include the placement of "dump rock" at problem areas, rock channel protection (RCP), soil, and other materials designed to resist bank erosion. Traditional stream management methods require ODOT to carry out extensive project development activities including environmental permitting, purchase and import of necessary bank protection material, deployment of heavy equipment, and highway lane closures. One potential alternative method for ODOT's stream management needs is the Palmiter stream management method. The Palmiter method utilizes the removal of logjams and other obstructions in combination with the strategic placement of on-site materials to direct river currents away from problematic erosional areas in the stream and realigning the channel flow. Because the Palmiter method emphasizes the use of in-situ materials and minimal equipment deployment, it may be more cost-effective and faster to deploy than ODOT's typical methods while also creating a more natural, less artificial, bio-engineered project. Consequently, if it can be shown that the Palmiter method can be cost-effective for ODOT stream management needs, the Department may realize significant cost and time savings while also improving the efficacy of its stream management activities.

RESEARCH BACKGROUND

Research Objectives

This project was carried out as Task #7 of the ODOT Office of Statewide Planning and Research (SPR) program project "Division of Planning Research On-Call Services" (PID 111440; SJN 136125). Researchers from the Ohio Research Institute for Transportation and the Environment (ORITE) at Ohio University, with assistance from the Energy and Environment Team of the Voinovich School of Leadership and Public Service at Ohio University and MS Consultants, Inc., completed all Task #7 work.

The goal of this task was to investigate the potential applicability of the Palmiter method as an alternative for ODOT to use for its erosion control and stream management activities. As noted in the Task #7 scope, the investigation needed to examine at least the following aspects of the Palmiter method:

1. Worker Safety
2. Labor, time, and dollar costs associated with implementation;
3. Crew sizes needed;
4. Regulatory requirements;
5. Training needed;
6. Ease of implementation
7. Number of visits needed to the same site over time;
8. Level of pre-construction data and design needed to implement;
9. Site/condition applicability; and
10. Creation of hazards for river users (e.g., waders and boaters).

Accordingly, the following specific objectives were pursued:

- Objective 1: Analyze the Palmiter method as it pertains to the previously-listed aspects of ODOT's stream management needs.
- Objective 2: Compare the Palmiter method with other ODOT stream management techniques on various aspects including the benefits and costs.
- Objective 3: Produce a technical brief to report the findings of the research task, including a matrix comparing the Palmiter method with other methods.

Palmiter Method Overview

The Palmiter stream restoration method is described in detail in a March 1982 report from the U.S. Army Corps of Engineers entitled *A Guide to the George Palmiter River Restoration Techniques* (Report No. 82-CR1, Institute of Environmental Sciences, Miami University) (Herbkersman, 1982). This report describes the procedures for a natural erosion control method established in the 1970s by Ohio resident George Palmiter. The basic concept of the Palmiter technique is to utilize in-stream materials (e.g., large tree trunks, woody plants, root wads, etc.) placed in strategic locations to restore the natural flow of the stream channel to a new or recent location. By restoring the flow of the channel to a new channel, the stream energy deposits sediments at the eroded banks, that have been moved from sand/gravel bars, or other blockages in the channel. Material used can be classified as large woody debris defined in this case as tree trunks with or without top branches removed with diameter greater than approximately ten inches and small woody debris including smaller logs, branches, tree tops, and shrubs. When tree tops are retained on large woody debris, they are emplaced with the tree top oriented downstream to retain sediment in the eddy created by the large woody debris. Small woody debris is positioned to retain sediment and is secured to the large woody debris. The use of natural materials to redirect flow and retain sediment can also encourage revegetation naturally or create areas for planting.

The original description of the Palmiter technique includes the following steps as noted in the 1982 report (Herbkersman, 1982):

1. Identification of Erosion Problem Area.
2. Remove Log Jams – Removal of fallen trees and log jams upstream from erosion area to restore the current of the stream to a previous and recent flow path.
3. Protect Eroded Banks – Placement and anchoring of large woody debris overlaid with small woody debris along eroded banks to prevent further erosion; the vegetation needed for this step can be obtained from the removal of log jams from Step #2 and other locations (Step #6).
4. Remove Sand and Gravel Bars – Where significant sand and gravel bars exist, they are removed by installing current deflectors or by digging pilot channels.
5. Revegetation – Reestablishment of appropriate vegetation to provide additional long-term bank protection and to provide shade for the river and its wildlife.
6. Remove Potential Obstructions – Removal of large trees that have fallen or otherwise obstruct the natural flow of the stream channel, as well as removal of trees in areas where erosion is desired to accomplish the project goals.

7. Maintenance – Periodic reexamination of the state of the stream channel to determine if the outcomes are being achieved or if any new work is needed.

The Palmiter method utilizes as much on-site natural material as possible in the construction. For example, large trees that are a threat to fall into the waterway due to erosion are cut and collected for use, or woody debris from log jams are collected and relocated for use in the project area. Large trees and logs (i.e., large woody debris) are secured to the bank directly to standing trees or using a "dead man" anchor system and small brush and other woody debris (i.e. small woody debris) are attached to larger trees or logs. The large woody debris installations can be secured parallel to the bank (i.e., bank armoring) or can be placed at an angle in the same direction as the stream slow to direct the stream energy away from a specific location (i.e., flow kicker). The small woody debris is used to promote sedimentation. Over time, these installations become part of a new bank. The flow is redirected away from problem areas and the stream energy is used to break down existing sand or gravel bars and, often, the bank opposite to the problematic erosional area, thereby creating a new channel alignment. In addition to utilizing in-situ materials for construction, the Palmiter techniques were historically intended to be carried out using human labor and readily-available hand tools rather than sophisticated construction equipment. However, recent installations have used heavy equipment on the banks and rope and pulley systems over the creek or river to move and reposition trees, eliminating the need for machinery in the waterway.

RESEARCH APPROACH

The research team approached the research goals and objectives with a work plan consisting of the following nine tasks, completed over a duration of six months. Additional details of the research approach components are described in this section.

- Task 7.1: Literature Review;
- Task 7.2: Survey of Potential Applicability of the Palmiter Method;
- Task 7.3: Regulatory Review;
- Task 7.4: Analysis of Pre-Construction Planning Requirements;
- Task 7.5: Analysis of Construction Requirements;
- Task 7.6: Assessment of the Palmiter Method;
- Task 7.7: Development of Training Content;
- Task 7.8: Recommendations and Task Deliverables; and
- Task 7.9: Project Management.

Task 7.1: Literature Review

Task 7.1 of this project was a detailed review of existing literature on the Palmiter method, ODOT practices for stream bank erosion management, and the extent of Palmiter installations currently in existence. Details of the Palmiter method components, as described in the U.S. Army Corps of Engineers' 1982 report detailing the technique (Herbkersman, 1982), reviewed as part of this task. Those details are presented in the "Palmiter Method Overview" section above.

ODOT uses a variety of erosion control and stream/bridge realignment techniques for protection and maintenance of road bridges and culverts. Typical activities include clearing waterways of debris that has been trapped upstream by banks and bridge supports; dumping riprap to armor eroding banks; dredging accumulated sediments; and adding structures to direct flow away from scouring areas (Witter and Mecklenburg, 2019). The primary method ODOT uses in the case of eroding banks and channels out of alignment with the bridge opening is to attempt to stabilize banks by dumping rock, commonly known as riprap. The nearly exclusive use of dump rock for erosion control was confirmed by several ODOT Districts in response to a brief informational survey that was distributed by the research team. While dump rock is somewhat effective in an emergency situation, the method offers little long-term protection and does not address the stream flow directed at the bridge or roadway that is causing the problematic erosion in the first place. Further background and literature review can be viewed in Appendix A of this report.

The literature review task of this project also included a review and analysis of specific locations where the Palmiter method has been used to protect infrastructure from stream bank erosion issues or for stream restoration. An Ohio-based vendor, Channel Maintenance Systems, currently provides stream restoration and erosion control services using the Palmiter technique. Multiple locations in Ohio where the method had recently been installed or was in the process of being constructed as of this research were identified by the vendor and analyzed by the research team. Site visits to these installations provided the research team with significant insight on the construction techniques and functionality of the Palmiter method. The site visits included various use cases for erosion control (e.g., bridge structure protection or roadway protection) and different stages of post-construction outcomes. The research team was able to observe how the specific construction techniques for the Palmiter method are executed in the field, including assembling flow kickers, various methods for anchoring woody material, and outcomes for targeted erosion or deposition according to the project work plans. Post-construction maintenance activities were also discussed, and the research team was able to observe how the changes were required in the early years following installation. Additional details of the existing Palmiter installations can be viewed in Appendix B.

One additional conclusion that was drawn from the site visits was that the Palmiter method was being used primarily for erosion control purposes and that there was limited use of the technique for "stream restoration" purposes as the term is generally understood. In particular, while the outcomes for erosion control were clearly visible at the installations, there was no visible evidence or data collection related to improved floodplain connectivity or ecological function. Consequently, the research team modified the research scope to focus primarily on matters related to erosion control with reduced emphasis on the stream restoration.

Task 7.2: Survey of Potential Applicability of the Palmiter Method

Task 7.2 of this project was a survey of the potential applicability of the Palmiter method for ODOT's erosion control needs. The research team analyzed data from ODOT's bridge and culvert inventory to identify any trends or patterns associated with bridge scour ratings or other evidence of erosion control needs. Preliminary analysis of available data sets indicated that the use of data items from common asset inventory data sets was of limited usefulness in identifying sites that could benefit from the Palmiter method. Additionally, there is no data or inventory compiled by ODOT to track its erosion control and stream maintenance activities. To obtain greater insight on current erosion control practices and site selection procedures, the research team reached out to Highway Management Administrators (HMA) for several ODOT Districts. The responses supplied by the HMAs provided useful information on ODOT's maintenance practices for erosion control. The HMA survey confirmed that most erosion control projects are identified through routine inspection of infrastructure or identification of specific problems as they arise. The survey also confirmed that the most common method of correcting erosion control issues is the riprap or "dump rock" option. In terms of project development, it was revealed that erosion control projects are generally added to the District's work plan promptly after identification. Additional details of the HMA survey questionnaire and specific responses are presented in Appendix C.

Task 7.3: Regulatory Review

Task 7.3 of this project was a review of the regulations and permitting requirements that would be applicable to an erosion control project that utilized the Palmiter method. Regulations and permits applicable to such projects include waterway permits, floodplain regulations, ecological-related regulations (e.g., T&E species), and right-of-way issues. Various manuals and guidance from ODOT Office of Environmental Services (OES) were used in the review, including the *Waterway Permits Manual* (ODOT OES, 2020c), *Ecological Manual* (ODOT OES, 2014), and the *Real Estate Manual* (ODOT Office of Real Estate, 2021). The research team also worked closely with applicable ODOT staff to assist with interpretations or current understanding of specific regulatory issues encountered during this review. Details of the permitting and regulatory review can be viewed in Appendix D of this report.

Task 7.4: Analysis of Pre-Construction Planning Requirements

Task 7.4 of this project consisted of an in-depth analysis of the project development and pre-construction planning requirements for a Palmiter method project. The pre-construction planning phase starts with the process of determining if the Palmiter method is feasible for use at a specific location where an erosion control problem has been identified by ODOT personnel. Key factors that influence the feasibility include the availability of woody material for construction and access to the site on both sides of the waterway along the length of the project extent. The extent to which each of these (woody material and site access) are available within the ODOT right-of-way, or if suitable right of way/access easement can be secured, will also be a critical factor in the suitability of the Palmiter method at a particular location. On the other hand, the technique may not be appropriate for stream widths over 100 feet or locations where structures are determined to be failure imminent. After it has been determined that the Palmiter method is suitable for a particular site, the pre-construction planning process is initiated. The primary activity of the pre-construction planning is the development of a scoping memo describing the erosion problems and a work plan showing the location of the proposed corrective actions needed. Detailed discussion of the pre-construction planning, including all site selection and project planning activities, can be found in Appendix E.

Task 7.5: Analysis of Construction Requirements

Task 7.5 of this project consisted of a detailed analysis of the construction and operational requirements associated with a Palmiter method project. Construction and maintenance requirements were analyzed assuming that ODOT personnel would be responsible for all aspects of both construction and long-term maintenance of the Palmiter project. The analysis of construction requirements synthesized the lessons gleaned from site visits and discussions with both the Palmiter method vendor and project owners (primarily local agencies), coupled with the planning and construction guidance detailed in the 1982 report on the Palmiter method (Herbkersman, 1982). The typical sequence of construction is to remove log jams or other undesirable vegetation and to then assemble these materials into flow kickers or bank armoring. Anchoring these assemblies to the bank can be done by direct attachment to trees or stumps that remain in place on the bank or through a “dead man” anchor. Analysis of the equipment and labor requirements was also completed as part of Task 7.5. The equipment requirements include chain saws, a small backhoe-loader (desirably with a grapple attachment for log clearing), and trucks to haul away excess material. Labor requirements consist of skilled laborers and equipment operators under the supervision of a foreman, all of whom are trained in the Palmiter method and familiar with the site-specific work plan. Task 7.5 also analyzed the post-construction operations and maintenance requirements for the Palmiter method project. It is anticipated that sedimentation will start to build up within 1 to 3 years following installation. Post-construction maintenance will ensure that the outcomes of the project are accomplished with annual site inspections (preferably after spring flooding or high-water events) and a one-day work session may be needed to carry out any follow-up maintenance needed. Detailed discussion of the Palmiter project life cycle, considering all aspects of project planning, construction, and operations, can be found in Appendix E of this report.

Task 7.6: Assessment of the Palmiter Method

Task 7.6 of this project was an assessment of the Palmiter method compared with other erosion control practices of ODOT. Based on the feedback provided by ODOT District HMAs, the predominant erosion control method currently used by ODOT is to dump rock at locations where erosion is affecting ODOT infrastructure. Other methods, as described in the literature review, are not as commonly used, and thus were not analyzed in this assessment. The assessment focused on all aspects of the decision-making process for selection of an erosion control method for a problem location. The results of this assessment are presented in the “Research Findings and Conclusions” section of this report.

Task 7.7: Development of Training Content

Task 7.7 of this study consisted of the development of content to aid in training ODOT personnel on the basics of the Palmiter method and the applicability of the

Palmiter method in different erosion control situations. The training content was created in the form of a narrated Power Point slide deck discussion site selection and pre-project planning needs.

Task 7.8: Recommendations and Task Deliverables

Task 7.8 of this study included the formulation of recommendations based on the results of the study as well as the development of the task deliverables. The recommendations and suggestions for implementation are reported in the "Recommendations for Implementation" section of this report. The deliverables for this task included this report and a poster describing the findings. The deliverables also include the training slide show developed in Task 7.7.

RESEARCH FINDINGS AND CONCLUSIONS

Discussion of Key Findings

The Palmiter method is a sustainable approach (i.e. the economic, social, and environmental costs and benefits are balanced through the relatively lower cost, aesthetically pleasing, lower environmental impact method when compared to dumping rock on eroding surfaces or building hardened erosion protection infrastructure) to managing erosion control issues on a stream or river that emphasizes the use of natural (woody) materials, sourced at or near the project site, to direct the stream's energy away from problem areas and to "let the river do the work" to solve issues over time (Herbkersman, 1982). Based on the research team's visits to several existing Palmiter installations, there is strong evidence to suggest that the technique is working for its intended purpose of managing stream bank erosion (in this application, to protect bridge and roadway infrastructure that is threatened by erosion issues). An example of how the technique is implemented is shown in Figure 1, drawing on the example of the Eleazer Road installation in Greene County. Figure 1 [a] shows the conditions of the site in the early stages of construction, including significant bank erosion on the right bank and a large gravel bar on the left side of the image. In the more recent (March 2021) view (Figure 1 [b]), the gravel bar has completely eroded and some sediment deposition has started within the installation area (Figure 1 [b], middle). Success in sediment deposition can be realized within 2 to 3 years of installation. For example, the Palmiter installation at the Heatherwoode golf course in the City of Springboro was completed in October 2018; by March 2021, sediment deposition in some locations was sufficient enough to support direct human activity (see Figure 2). In the long-term, there is limited evidence that there were ever any bank erosion issues present at a site or that a project using the Palmiter method was completed, (see Figure 3 showing the view of a site where the project was completed more than 20 years ago).

The Palmiter method is a long-term, permanent solution to repair stream bank erosion issues that represents a fundamentally different approach than what ODOT currently uses for its erosion control and stream maintenance projects. Nevertheless, the method holds significant promise as a "tool in the toolbox" for ODOT's erosion control and stream management project needs. An assessment of the potential for ODOT's adoption of the Palmiter method is presented in the following section.

[a] View during early stages of construction facing upstream from bridge. Note significant erosion of channel on right side of view. Photo Source: Ron Wine, CMS, June 2019

[b] Post-Construction view looking downstream towards bridge structure with Palmiter installation completed. Photo Source: Ben Sperry, OU, March 2021

Figure 1: Palmiter Installation at Eleazer Road, Greene County

Research Team Member Standing in Deposition Area.
Photo Source: Matt Perlik, ODOT, March 2021

Figure 2: Heatherwoode Installation, Sediment Deposition Area

Location: Stillwater River, Barnes Road, Webster Township, Darke County. Installation completed over 20 years ago. Photo Source: Elizabeth Myers, OU, May 2021

Figure 3: Upstream View of Long-Term Palmiter Installation

Assessment of the Palmiter Method for ODOT Applications

This section presents an assessment of the Palmiter method for ODOT's erosion control and stream management project needs. The assessment presented herein is based on the research team's understanding of the work activities and requirements for the Palmiter technique, informed by actual experiences viewing Palmiter installations alongside long-term experience in stream hydrology. It is also informed by the research team's understanding of the regulatory and waterway permitting requirements that ODOT must comply with on all of its projects. Further, it is the understanding of the research team that ODOT's goal is to assess the ease of implementation of the Palmiter method utilizing ODOT's in-house resources (e.g., District planning personnel and County Garage maintenance forces) to carry out these projects. In this context, the assessment of the Palmiter method for ODOT use is discussed in the following sections.

Worker Safety

The Palmiter method requires equipment operators to work on streambanks and near roadways to dig trenches for anchors and to place large woody debris, requiring both experience and care to maintain safe conditions. Workers will likely need to work in waders in the stream to secure large woody debris and to place and secure small woody debris. Personnel experienced in the use of waders and in working in/near flowing water can mitigate some risk associated with in-stream work. Tree removal and cutting of woody debris poses a risk to workers both in falling trees and limbs and use of chain saws. Specialized training and safety equipment should be provided to workers to mitigate these risks. Some ODOT maintenance forces are already trained in the proper use and safety hazards associated with the use of chain saws for tree cutting activities due to this work already taking place within ODOT along highway right-of-way across the state.

Labor, Time, and Dollar Costs

All of the necessary labor, tools, and equipment needed to carry out a Palmiter installation are available at a typical ODOT County Garage or can be easily obtained. Equipment requirements for the Palmiter method construction include chain saws, a small backhoe-loader with grapple attachment for moving woody material, and a dump truck or work truck to haul away excess material. A tow truck may also be used to set up a winch system across the stream for the moving and placement of large woody debris. It is anticipated that the equipment required to carry out the Palmiter method is available at ODOT's county garages or could be shared among several garages if needed. The labor, tools, and equipment requirements for follow-up maintenance visits are similar to those required for construction and thus it is feasible to use in-house forces in that phase.

Regarding the time requirements, the duration of the construction will be based on the extent of the erosion control activity and the productivity rate of the work crew. It is assumed that the primary unit of work for the Palmiter method is the bank armoring or flow kicker assembly consisting of a single large tree or log attached to the bank via tree or "dead man" anchor, with small woody debris used for stability and sedimentation as appropriate. The work required to assemble a single unit includes preparation of the large log/tree (cut down or import), placement in the stream according to the work plan, securing to the bank, and attach small woody debris, as needed. Based on experiences from existing Palmiter installations in Ohio, the average construction time is approximately 3 to 5 days using a trained work crew with an average of between 2 and 4 bank armor or flow kickers installed per day. As ODOT crews gain more experience with the techniques of the Palmiter method, the efficiency of the construction activities will increase to optimal levels.

Regarding construction costs, evidence from existing installations indicates that the costs of construction for the Palmiter method are generally less than or equal to the costs for alternative methods that were considered at the sites (on a per linear foot basis, see Table 2). It is unclear to what extent ODOT performs a cost analysis for any of its stream maintenance activities, making it difficult to estimate the corresponding costs for ODOT to implement the Palmiter method. The Palmiter method is a labor-intensive, long-term erosion control strategy, while ODOT's current primary erosion control method (dump rock) will have higher material costs but is also a short-term fix since no stream energy is affected by this repair technique and, therefore, the root causes of erosion are not changed. Material costs for the Palmiter method will also be affected by the availability of on-site materials, with costs being substantially higher if large trees need to be imported from off-site.

Crew Sizes Needed

Regarding the labor requirements, it is anticipated that a crew of 3-4 laborers with a supervisor would be needed to carry out an erosion control project using the Palmiter method. A skilled equipment operator would also be needed to operate any equipment that would be required. The work crew would need to be trained on the specific techniques of the Palmiter method by an individual with experience in the method. In addition to training on the specific construction techniques, safety training for work with chain saws and work in/around waterways would be required for the crew. It is likely that ODOT County Garage work crews are already formed in this manner or can be easily organized.

Regulatory Requirements

Regarding waterway permitting concerns, the research team finds that the Palmiter method offers no significant streamlining or advantages over other methods of erosion control. All activities associated with the Palmiter method are anticipated to have minimal impact to waters of the U.S. and will be authorized under the ODOT Regional General Permits (RGP) B and C, subject to certain site-specific conditions that affect all stream-related work of ODOT (e.g., mussel surveys). Any project work that would require heavy equipment to operate in or traverse a waterway would require additional permitting and ecological protections (e.g., mussels). Given the unique nature of environmental conditions and the scale and needs of each project, projects will likely have to be evaluated on a case-by-case basis; once the impacts are better-understood, ODOT could pursue a programmatic agreement for the work as appropriate. It should be noted that this conclusion represents the research team's interpretation of the applicable waterway permits; only the regulatory agencies with jurisdiction over a specific resource can provide conclusive determination of the permits required for the Palmiter method. Regarding other regulatory concerns, in particular those associated with protected bat species, the research team finds that a suitable wooded habitat (SWH) determination will be required for each project where the Palmiter method is to be used. Because the Palmiter method relies significantly on woody material sourced at or near waterway problem areas, the impacts on protected bat species will be heavily-dependent on the site-specific conditions and the condition of trees to be removed for use in the Palmiter project.

Training Needed

The Palmiter method represents a new technique for ODOT's erosion control projects and, as such, there is no specific in-house knowledge on the method. Certain aspects of the method, such as the use of chain saws and the removal of woody material, are very familiar to ODOT maintenance forces. However, training will be necessary for certain project planning requirements (e.g., work plan development) and the construction techniques for the Palmiter method (e.g., assembling and placement of flow kickers). With proper training on construction techniques and safety, ODOT's in-house maintenance forces have the skills and competency needed for completing all the necessary steps for the Palmiter method.

Ease of Implementation

Regarding the construction and maintenance project phases, implementation of the Palmiter method should be relatively straightforward with proper training on construction techniques and safety. Regarding the project planning stage, implementing the Palmiter method will require more complexity than what is typically required for a traditional erosion control project. In particular, consideration of the Palmiter technique will require ODOT's maintenance teams to examine the conditions of the waterway beyond the areas typically examined during routine inspections. Evidence of bank erosion will need to be identified upstream of the site (as much as 1,000 feet upstream in some cases) to determine the hydrologic conditions affecting erosion at the bridge or roadway. To ensure proper bank access along the full affected length of the work, it is likely that work will be required outside of ODOT's right-of-way to complete the installation activities. Determination of the specific right-of-way boundary and securing easements for the work will add tasks in the project planning stage that are not normally required.

Long-Term Maintenance

Pertaining to the post-construction maintenance and operations requirements, it is anticipated that ODOT would need to visit project sites at least once annually (likely after high water events) during the first 3 to 5 years following construction. The visits are to review the installation and make minor adjustments to the project elements as appropriate. It is likely that these maintenance visits would be relatively short (one day) and could be carried out with a smaller work crew than the construction work. However, the post-construction maintenance is a necessary step to ensure that the desired project outcomes are achieved.

Pre-Construction Planning Requirements

Regarding the project planning requirements, development of a work plan for the Palmiter method should be relatively straightforward for ODOT personnel with proper training on the method. The complexity of the work plan will depend on the extent of the bank erosion problem at the project site and the availability of on-site materials for the work. Additional time required for project planning will depend heavily on the availability of right-of-way for the work and the regulatory/permitting issues associated with a specific site. For example, if a complicated right-of-way process is anticipated, the project planning could be significantly longer than if the work can be contained within the existing ODOT right-of-way. Given that each potential site presents a unique scenario as it relates to these factors, it is difficult to generalize the time and cost requirements for project planning.

Site and Condition Applicability

Regarding the applicability of the Palmiter method for ODOT's stream bank erosion control projects and other stream management needs, it is concluded that the method is applicable to a wide range of issues faced by ODOT. Since the Palmiter method is not a quick-fix, sites where erosion is too severe, or infrastructure damage or failure is imminent are not good candidate sites for use of the Palmiter method without action to halt damage to bridge or roadway infrastructure. Other key limitations on the applicability of the method include the river channel greater than 100 feet wide; limited availability of woody material on-site; and the suitability of site access for construction and permanent installation of the Palmiter features.

Creation of Hazards for River Users

Based on the experiences of Palmiter installations to date, it is concluded that the Palmiter method poses little risk to waterway users (e.g., waders or boaters). One site the team visited was on a scenic river frequented by kayakers; the project installation did not protrude into the river and, since the purpose of the Palmiter method project was to create a depositional area by using kickers to divert flow and create an eddy, boaters would naturally paddle away from the project area to stay in the current. Soft sediments that accumulate in the project area may pose some hazard to recreational activities on those areas. Additionally, there may be some concerns about vandalism or modification of the installations by individuals who are unaware of its purpose. These issues can be mitigated by placing signage at the project location and notifying key river users (e.g., parks or canoe liveries) or other river-oriented organizations of the existence of the installation; while the team did not observe signage for river users, this is a common approach for other potential river hazards and stream restoration projects the team has worked on in the past.

Summary and Comparison Matrix

It is the key conclusion of this research task that the Palmiter method is a viable option for ODOT's erosion control and stream management activities. Considering all relevant aspects of project planning, construction, and operations of erosion control or stream management projects using the Palmiter method and the method customarily used by ODOT for this type of work (dump rock or riprap), a matrix comparing the two methods is presented in Table 1. For each row of Table 1, a brief discussion of the implications for each method is presented.

Table 1: Comparison Matrix of Palmiter and Dump Rock Methods

	Palmiter Method	Dump Rock/Riprap
Project Planning		
• Site Applicability	Most Cases; Not Suitable for Emergency Situations; On-Site Trees Desirable but Not Essential	Most Cases; Not Suitable for Areas Where a Natural Aesthetic is Essential (e.g., Scenic River or Park).
• Planning Data Needed	Similar to Dump Rock; Field Review Needed Using Site Checklist	Process Well-Established
• Planning Time Required	Additional Feasibility Studies Needed to Formulate Work Plan	Process Well-Established
• Waterway Permitting	Unknown; Minimal Impacts on WOTUS Anticipated (RGP C or NWP 27)	Process Well-Established (RGP B or NWP 3)
• Right-of-Way Needed	Stream Bank Access Needed Along Full Length of Project Area	Typically, None
• Other Regulatory Concerns	Impacts to Bat Species; Mussels and Fisheries Impacted if In-Stream Work is Needed	Typically, None; Mussels and Fisheries Impacted if In-Stream Work is Needed
Construction and Maintenance		
• Labor Effort Required	Typical ODOT Work Crew	Typical ODOT Work Crew
• Time Required	Anticipated 3 to 5 Days	Anticipated 3 to 5 Days
• Materials Required	Primarily On-Site Materials (Woody Materials)	Materials Imported (Dump Rock)
• Equipment Required	Hand Tools and Small Excavator; Tow Truck in Some Cases	Dump Truck and Large Excavator Required
• Construction Costs	Primarily Labor Costs	Primarily Material Costs
• Worker Safety Concerns	Water-Related Hazards; Falling Trees	Heavy Equipment and Large Rock Hazards
• Roadway User Concerns	Minimal Hazard; No Lane Closures Anticipated	Lane Closures Required
• Maintenance Required	Annual visits required.	Limited/None
• Training Required	Personnel training needed.	Personnel have expertise.
Overall Assessment		
• Ease of Implementation	Learning Curve Needed	Process Well-Established
• Constructability	Low/Some Complexity	Low/No Complexity
• Effectiveness in Short-Term	Limited	Substantial
• Effectiveness in Long-Term	Substantial	Limited
• Hazards for Water Users	Limited/None	Some in Project Area
• Hazards for Bank Users	Limited; Easily Mitigated	Substantial

RECOMMENDATIONS FOR IMPLEMENTATION

Recommendations

Based on the findings and conclusions of this research task, the research team presents the following recommendations for consideration:

- Recommendation #1: The Palmiter method should be adopted by ODOT as a "tool in the toolbox" for addressing stream bank erosion and related stream management issues that affect its infrastructure.
  Evidence from existing Palmiter installations indicate that the method can be carried out with ODOT resources (County Garage maintenance crews and equipment) in a safe and cost-effective manner. Worker safety can be maintained through training of personnel who would be working in chest waders in stream, utilizing heavy equipment near a stream, or using chainsaws. Based on the experiences of existing installations, the costs are less than or equal to the costs for traditional alternatives (see Table 2). The Palmiter method appears to be successful as a sustainable, long-term solution for stream management for a range of erosion-related problems in a variety of contexts.
- Recommendation #2: ODOT should undertake a pilot project utilizing the Palmiter method at a site where erosion control repairs are needed.
  The first step to full adoption of the Palmiter method for ODOT's erosion control toolbox is to undertake a pilot project using the method. Routine inspections during late summer 2021 may reveal several sites of interest for testing both the planning tools from this research task as well as the construction methods using ODOT forces. For the pilot study project, it is recommended that ODOT coordinate with the Palmiter vendor (Channel Maintenance Systems) to direct the work and that an observational study be conducted to collect data on work productivity as well as before/after stream channel conditions. While the method is applicable for any context, it may be useful for the pilot study to be completed in a low-risk setting, such as a two-lane rural highway, to minimize the impacts of iterative work associated with the anticipated "learning curve" for the construction activity.
- Recommendation #3: ODOT should retain the services of the Ohio-based Palmiter method vendor, Channel Maintenance Systems, to develop a detailed training plan for maintenance supervisors.
  If the pilot study (Recommendation #2) is successful, it is recommended that ODOT utilize the services and expertise of the Palmiter method vendor (Channel Maintenance Systems) to develop a detailed training plan for maintenance supervisors and conduct training sessions around the state. The training plan should emphasize the specific construction techniques and safety considerations associated with the Palmiter method.
- Recommendation #4: ODOT should develop an intra-agency working group that will take responsibility for managing the nuances of project development and pre-construction planning for Palmiter method projects. As noted throughout this report, there are several planning-related items that represent unknowns as it pertains to the Palmiter method (e.g., the need for a bat habitat survey or

right-of-way issues). Accordingly, it may be appropriate for an intra-agency working group to be assembled to encourage communication and collaboration across the various impacted areas of the Department (ecological, waterway permits, real estate, District HMA, hydraulic engineering, highway operations, etc.). This working group would be responsible for “ironing out” any streamlining or coordination needs and to preserve the institutional knowledge that is gained as ODOT rolls out more Palmiter installations over time.

Implementation Plan

To advance the recommendations of this research task, the following implementation strategy is proposed. To implement Recommendation #1, relevant stakeholders within ODOT will need to analyze the information provided in this report and determine if further investments in the Palmiter method is warranted. For Recommendations #2 and #3, implementation will require ODOT to partner with the Ohio-based vendor of the Palmiter method (Channel Maintenance Systems) to aid in “ramping up” the Department’s capabilities through a pilot study and, ultimately, some type of training program for in-house forces. Implementing Recommendation #4 will require identifying process owners within the various Central Office Divisions and Districts affected and assembling a working group to oversee planning activities. One possible outcome of the internal working group is a recommendation for modifications or adjustments to the various programmatic agreements that ODOT has with resource agencies to allow for Palmiter method activities to be carried out in a more streamlined manner. It is noted that ODOT’s efforts to coordinate across the organization and streamline processes in other aspects of the project development process has been quite successful at improving project delivery; implementing Recommendation #4 will likely yield similar results for Palmiter method projects.

To aid in the implementation of the Palmiter method for erosion control and stream management, the research team has developed several tools to support ODOT’s workflows at all stages of the project life cycle. A “Site Review and Decision Matrix for Project Planning” document was created to aid in the site selection and pre-construction scoping process (please see Figure 4 and Figure 5 on the following pages). Expanded discussion of this document is presented in Appendix E of this report. Additionally, the following tools are provided:

- Example work plan provided by Palmiter method vendor (Figure 21);
- Concept sketch (Figure 22) and accompanying plan notes (Figure 23) for key components of the Palmiter method installation; and
- A narrated Power Point slide deck to be used for training on site selection and pre-project planning needs (provided to ODOT separately).

Additional guidance on implementation of all aspects of the Palmiter method can be gleaned from the 1982 U.S. Army Corps of Engineers report (Herbkersman, 1982). Additional guidance on the construction of flow kickers, a key element of the Palmiter method, can be found in Guide #11 of the *Ohio Stream Management Guide* published by the Ohio Department of Natural Resources (ODNR, 2007).

Palmiter Method Site Review and Decision Matrix for Project Planning:

Site Visit Checklist:

- ✓ Complete This Project Planning Questionnaire
- ✓ Take photographs of entire site
- ✓ Measure length of site, stream depth, estimate bankfull height, location of right of way, etc.
- ✓ Measure stream velocity and/or flow or gather data from nearby USGS gage station (drainage area and peak flows)

Site Characteristics:

1) Is there evidence of bank erosion that will threaten ODOT structures at bridge, culvert, or roadway within the next 2-3 years? **If yes, answer questions a. - h. and continue. If no, Palmiter Method is not applicable.**

  a. Describe the severity of the scour of bridge or culvert.
  b. Is erosion leading to undermining of a roadway?
  c. Is the main flow of the stream directed at the eroding surface?
  d. Is there a depositional area (e.g. sand or gravel bar) forming in opposition to the erosion?
  e. Are the eroding banks caused by an obstruction that can be removed? Is a log jam or fallen tree directing the force of the water towards the bank?
  f. What is the distance of the eroding banks? Number of meanders within this distance?
  g. Number of log jams/brush piles in the stream within this distance?
  h. Does the river have access to the floodplain?

2) Is the bridge waterway adequacy large enough to allow for high flows? **If yes, continue. If no, Palmiter Method is not applicable.**

3) Is failure of structure imminent? **If no, continue. If yes, Palmiter Method is not applicable.**

Site Access and Hydrologic Conditions:

4) Is there safe access, both at the road and in the stream for personnel**?** **If yes, answer a.- d. and continue. If not, Palmiter Method is not applicable.**

  a. What is the water depth?

Figure 4: Site Review and Decision Matrix for Project Planning Page 1

b. What is the velocity?
c. What is the drainage area and peak flow?
d. What is the bankfull height?

5) Is the eroding surface/problem area within the ODOT right of way**? If yes, continue. If no, answer a.**

a. Is the upstream landowner willing to grant ODOT access and permission to access the property? **If yes, continue. If no, Palmiter Method is not applicable.**

Site Riparian:

6) Is there abundant woody material available on site (i.e. large woody debris in the creek; live trees and brushy material in riparian area)? **If yes, answer a. - d. and continue. If no, answer e.**

a. What type of vegetation exists on-site?
b. What is the maturity/size?
c. What are the predominate tree species in the corridor?
d. Are there dead standing trees overhanging the creek? If the trees were to fall, would they contribute to erosion? Do their roots stabilize streambanks?
e. Can woody material be obtained and imported to the site? **If yes, continue. If no, Palmiter Method is not applicable.**

Permitting:

7) Is there access on both sides of the stream/river to avoid heavy equipment in the stream**? If yes, continue. If no, answer a.**

a. Are freshwater mussels present in the stream? **If yes, contact ODNR and USFWS** to coordinate guidance on a possible mussel survey and 401-permit application. **If no, an ok candidate for Palmiter Method**, proceed with permitting process for an NWP 27 and coordinate tree removal during November – March to avoid Indiana Bat roosting April – October. Notify local liveries and municipalities if streams are used for recreation of safety concerns for users.

8) **A good site candidate for Palmiter Method**, proceed with permitting process for RCP C and coordinate tree removal during November – March to avoid Indiana Bat roosting April – October. Notify local liveries and municipalities if streams are used for recreation of safety concerns for users.

Figure 5: Site Review and Decision Matrix for Project Planning Page 2

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APPENDIX A: LITERATURE REVIEW

Summary of Stream Management Issues

The Palmiter Method, developed in the 1970s by George Palmiter, uses woody debris, bank seeding, and sand and gravel bar relocation to manage bank erosion. The method employs preferably onsite materials and woody debris anchored to stable banks or established trees to slow and redirect river currents, relocating erosive forces and encouraging deposition along previously eroded banks. Work is ideally done by hand, with minimal intrusion into the stream with heavy machinery (Herbkersman, 1982). Ohio Department of Transportation (ODOT) and county maintenance crews desire a low-cost method with minimal need for outside materials and equipment, and little or no need for additional permitting. This review of current literature compares common erosion control techniques to the Palmiter Method for bank erosion control around critical infrastructure. The method is not intended to address scour, the erosion subset of more deeply evacuated areas immediately around fixed structures but will indirectly reduce scour by aligning stream flow perpendicular to bridges so that supports are in line with flow.

While Palmiter presented his activities as a stream restoration method (Herbkersman, 1982), it does not meet the general principles of stream restoration as they are understood today. Specifically, the method does not improve floodplain connectivity, and there is no data supporting improved ecological function. It does, however, provide a more natural, low-tech, low-cost, longer-term alternative to currently employed erosion control methods. As originally written, the Palmiter Method employs six techniques for stream management (Herbkersman, 1982). This review will focus on updated application of the method which primarily uses strategic placement of trees and other woody debris to facilitate flow redirection. These activate the main principle of the Palmiter Method: “Let the river do the work” (Herbkersman, 1982). Directing the main channel flowlines to be parallel to the banks and perpendicular to bridges relocates sand and gravel bars and decreases the scour and erosion expected in the meanders of a river. Strategic use of this flow redirection can reduce erosion at bridges, culverts, or roadways and protect infrastructure.

Bank erosion is a natural and desirable feature of stream and rivers (Florsheim, 2008), and any prevention of that process will be counter to the natural tendencies of a stream that lead to a relative stable ecosystem. Traditional erosion control methods can also prevent the creation of naturally occurring pools and riffles essential for high quality fish (Kuhnle et al., 2002) and macroinvertebrate (Logan and Brooker, 1983) habitat, as well as promoting higher biodiversity and resilience (Cook and Sullivan, 2018, Mathews and Mecklenburg, 2006). However, when it threatens road infrastructure, erosion must be controlled to preserve function and safety of the roadway. Various measures offer effective ways to prevent bank erosion to protect infrastructure, but there can be unintended consequences. When protecting a bridge or single bridge component it is possible that the problem is simply shifted elsewhere (Smith and Ritter, 2009).

Bridges and structures situated over waterways are particularly vulnerable to degradation due to the dynamic nature of water. Channels have erodible boundaries that change shape and orientation in response to hydrological events and adjacent land use. Scour, a type of erosion that loosens dirt and sediments around immovable objects in a stream channel (e.g., bridge supports) leaving a deeper floor than in the rest of the channel, can undercut and threaten the stability of built structures. According to a report on protecting bridge waterways against scour by the Iowa Highway Research Board, the bridge components of concern due to scour are the upstream channel, the bridge opening (abutments, approach road embankments, piers, and drainage courses flanking the abutments), and the downstream channel (Ettema and Muste, 2006). In other words, all areas upstream, downstream, and in the immediate area of the bridge need protection from the force of water in erosional events. The heaviest erosion in waterways happens on outside bends where erosion tends to have the biggest impact on the streambank (Constantinescu et al., 2013). When this occurs, the inside of the bend will develop a bar that continues to push the water to the outside bend. Through the natural meander of rivers, these bars eventually become vegetated and are no longer part of the channel. In areas around infrastructure, however, channels cannot always be allowed to meander naturally.

Review of ODOT Stream Management Techniques

ODOT uses a variety of erosion control and stream/bridge realignment techniques for protection and maintenance of road bridges and culverts. Typical activities include clearing waterways of debris that has been trapped upstream by banks and bridge supports; dumping riprap to armor eroding banks; dredging accumulated sediments; and adding structures to direct flow away from scouring areas (Witter and Mecklenburg, 2019). The primary method ODOT uses in the case of eroding banks and channels out of alignment with the bridge opening is to attempt to stabilize banks by dumping rock, commonly known as riprap. Somewhat effective in an emergency situation, the method offers little long-term protection and does little to address the physics of water's force.

Previous studies have explored what types of built structures provide optimal erosion control function with consideration of cost, manpower, and permitting. Witter et al., (2017) compared the use of single-arm vanes, w-weirs, two-stage channels, rock channel protection, bank grading, and live stake plantings to realign stream channels to bridges and correct problematic erosion. The study concluded that while longer study is necessary, in the short term, single-arm vanes combat lateral stream migration. W-weirs upstream of lower flow culverts effectively allowed for the clearing of sediments by increasing slope to concentrate the flow and temporarily trapping sediments on the upstream side, which then cleared in higher flow events. Additionally, the projects in close proximity, generally connected to the bridge or culvert structure, were determined to be covered under the Regional General Permit Section B, or the Nationwide Permit #3 (Witter et al., 2017).

Upstream erosion countermeasures include temporary and permanent seeding, inlet protection, filter fabric or rock ditch checks, bale filter dikes, dike and slope protections, and sediment basins or traps (Morris et al., 1999). Inlet protections, sediment basins and traps, ditch checks, and bale filters all work similarly in that they allow water to flow through a barrier, while holding sediment on the upstream side.

These measures are generally temporary installations used to prevent sedimentation downstream of construction sites and not sustainable for long term corrective action.

Permanent seeding on disturbed areas by establishing perennial vegetative cover is effective at reducing erosion, decreasing sediment yields from those disturbed areas, and providing permanent stabilization (Rivas, 2006, Gray and Sotir, 1996). Uniformly distributed vegetation on streambanks have been shown to decrease bank retreat, stabilize banks, and tighten meander bends (van Dijk, 2013). However, regular inspections of permanent seeding installations are necessary to ensure that plants become established and that any erosion or plant loss is addressed during the period of establishment. Establishment to a functional level also takes more time than can generally be practical in infrastructure protection or a corrective project. Therefore, seeding is recommended in conjunction with other measures for increased functionality long term.

For upstream channel control, guide banks, hardpoints, spur dikes, bendway weirs, and vanes are utilized. Guide banks are meant to confine and guide water through bridges to minimize scour of the approach embankments and prevent resulting damage to the bridge support (Gray and Sotir, 1996; Witter et al., 2017; Witter and Mecklenburg, 2019). Hardpoints have been shown to be effective in preventing scour where installed (Smith and Ritter, 2009), but have also been shown to increase scour just downstream of the installation (Taniguchi et al., 2017).

Figure 6 shows the stream extending portion of hardpoints using large woody debris. In this method, large downed trees are buried into the bank to provide bank structure and the exposed portion reduces water energy to the bank. One negative aspect of hardpoints is that scour can still occur if the energy dissipated is transferred to unprotected areas adjacent to its effective area. The fixed points also have no mobility whatsoever and can be overtopped in high flow events.

Spur dikes (Figure 7) are rocky outcrops installed to divert flow to the center of the channel and away from the banks. Spur dikes have been shown to be an effective way to prevent bank erosion (Copeland, 1983, Shields, 1988). Bendway weirs are almost identical in structure to spur dikes but are designed to be topped by the water and this flow over the weir is directed to the center of the channel; however, a report by the Indiana Department of Transportation found this method to offer little protection from bank erosion. Vanes (Figure 8) have been shown to be effective at erosion control by directing flow to the center of a channel (Witter et al., 2017).

Riprap (Figure 9) is a commonly employed tactic for channel control and abutment protection. Riprap is the layering of rock or other material used to reinforce banks to minimize erosion. This is commonly used effectively on lakeshores that periodically experience high swells and bank erosion is a concern. Riprap is effective at preventing bank erosion on the portion of bank where it is installed (Blodgett and McConaughy, 1986), however it can cause greater erosion downstream by increasing the speed of the flow (Smith and Ritter, 2009). This method is generally the default technique for agencies because it is easy and has an immediate, albeit short term, effect. Riprap will eventually succumb to erosion if flow forces are not redirected away from the reinforced bank.

Source: Engineering with Nature, FEMA (Smith and Ritter 2009)

Figure 6: Example of a Hardpoint Using Woody Debris

Source: U.S. Army Corps of Engineers, licensed under CC BY 4.0

Figure 7: Example of a Spur Dike

Source: Witter, et al., 2017

Figure 8: Example of a Vane

Photo Source: Ben Sperry, OU

Figure 9: Riprap Applied for Bank Stabilization

Summary of Palmiter Stream Management Technique

The Palmiter method uses wood already present in the stream to perform stream management functions, while it was initially proposed as a stream restoration method. The original six-activity method has been modified to two or three active tasks, depending on site needs and conditions: 1.) Logjams that cause unwanted sedimentation and block or misdirect flow are removed from the stream, typically upstream from problematic erosional areas, but may also be removed downstream to ensure free-flowing conditions; 2.) Large, downed trees (called "kickers") are anchored at a specific angle to oncoming flow, typically 30 – 40 degrees, to redirect flow back to stream center; and when possible and necessary, 3.) Revegetation of depositional areas and removal of vegetation from sand and gravel bars that will be removed through river flow, as needed (Ronald Wine, Channel Maintenance Systems, personal communication, March 19, 2021).

Cleared logs are repurposed for bank protection by placing them on eroding banks to prevent further degradation in similar fashion to a riprap, or revetment, in a fixed position as a hardpoint would be. The large woody debris is moved with a small excavator and guided into place using the cable on a tow truck; this system requires access to both sides of the stream. The kicker trees are anchored to solid standing trees, or to large logs buried perpendicular to the eroding bank in a t-shaped trench, using cable. The cables allow limited movement of the kickers to allow for some protection against overtopping flow that would erode banks above. Bundles of smaller woody debris are often secured between the bank and the kickers to maintain the proper angle, provide friction, and retain sediment. Trees are anchored with branches downstream, to slow water and encourage sediment deposition. Over time, the installations become a part of the new bank. The new flow path of the river then does the work of gravel bar and channel relocation, over time (Ronald Wine, Channel Maintenance Systems, personal communication, March 19, 2021).

In the report by the U.S. Army Corps of Engineers (Herbkersman, 1982), the removal and repurposing of wood is done primarily by hand labor using tools like saws, winches, axes, etc. If wood manipulation is difficult or not possible by hand, or if the water is too deep to safely operate tools, then a small barge or boat or the cable on a tow truck used as a guide line across the stream may be used. Occasionally, machinery like tractors or excavators may be necessary to move wood in the stream, but should be avoided, if possible, to reduce negative impacts on stream. Recent work has been performed using heavy equipment on the banks and rope and pulley systems over the creek or river to move and reposition trees, eliminating the need for machinery in the creek (Ronald Wine, Channel Maintenance Systems, personal communication, March 19, 2021).

In addition to aesthetic advantages of using natural materials as opposed to built structures, awareness of the ecological benefits of large wood to aquatic biota in forested ecosystems has steadily increased. Wood is an essential mechanism for energy dissipation in streams (Bilby and Likens, 1980; Curran and Wohl, 2003) and provides cover and habitat for fish (Benke et al., 1985; Harmon et al., 1986). In addition, wood contributes positively to channel stability (Shields, 2000; Abbe and Montgomery, 2003) and aquatic biodiversity (Wondzell et al., 2003).

An unpublished student design project in 2021 analyzed various alternatives for an erosion control project along a 320-foot section of the Hocking River near Chauncey, Ohio. Cost analysis completed by the students found that the property owner would spend approximately $2.5 million to install riprap at the study site, where their estimation of cost for the Palmiter method at the same site was $28,900.00. While only a student project, the cost estimate difference is striking enough to warrant additional investigation as it appears the method results in significant cost savings (Mitten, et al. 2021).

The Palmiter method is applicable primarily to low-gradient, alluvial streams and small rivers to address logjams causing increased sediment deposition, increased flooding, and unstable streambank conditions of erosion (National Research Council, 1992). It is an effective method of channel alignment, erosion control and gravel bar relocation (Herbkersman, 1982).

Site visits to completed projects (see Appendix B) indicate that the method is useful for protecting bridge and road infrastructure where erosion is evident. Adequate woody debris and access to eroding banks without need to take machinery across the stream channel are also necessary for a streamlined project.

The Palmiter Method is not applicable to structures determined to be in danger of immanent failure from erosion or scour. Success relies on the natural processes of erosion and deposition, which is constant, but slow. While some effects of flow redirection by tree kickers can often be seen immediately, and erosion will therefore significantly slow, flow rates, high flow events, and mobilized sediments will impact the rate at which banks are able to re-establish. The process can take years (Ronald Wine, Channel Maintenance Systems, personal communication, March 19, 2021).

Wood removal from streams has been shown to increase bed erosion and channel widening, as well as exposing sediment sources for transport when wood is removed (Brooks, 2006; Brooks et al., 2006). Revetements direct the stream energy elsewhere, essentially displacing that power and moving the erosion. Wood manipulation and removal thus has the potential to negatively affect energy dissipation, fish and other biota habitat, channel stability, and aquatic biodiversity, if the transferred erosion becomes a problem downstream. When carrying out this portion of the method, downstream sediment traps can work to prevent excess sediment transport.

As an infrastructure protection technique, the Palmiter method is attractive as it does appear to have some beneficial outcomes for stream health and function, requires few outside resources, and appears to have longer term benefits and lower costs, while requiring no additional permitting restrictions or requirements than other streambank stabilization techniques currently employed by ODOT.

APPENDIX B: DETAILS OF EXISTING PALMITER INSTALLATIONS

Introduction and Summary

This appendix reports the details of several existing installations of the Palmiter method for erosion control in Ohio. The research team visited sites in Greene County, Summit County, Warren County, and the City of Springboro to observe the installations and collect information about the extent and performance of the erosion control taking place. The information and data reported in this appendix was gathered by the research team with some details confirmed by the Ohio-based vendor of the Palmiter method (Channel Maintenance Systems). Project cost data for the Palmiter installations were obtained from public records (e.g., Ohio Checkbook online) or requested from project owners. For some projects, the Palmiter installation was preceded by an attempt to resolve erosion issues at the project location using traditional methods (e.g., rock channel protection or retaining walls). Project costs for those projects were obtained from project sponsors or research team estimates of traditional restoration costs. A summary of the key metrics for the existing Palmiter installations is presented in Table 2. It is evident from the information presented in Table 2 that the Palmiter method has been utilized in a range of use cases and project contexts. The costs for the Palmiter technique are approximately $140-$180 per linear foot of stream impacted for smaller installations and $90 per linear foot for the one larger project in Springboro. The City of Springboro also has a five-year contract with the Palmiter vendor for the amount of $17,000 per year to maintain the two installations in its jurisdiction. Examining the cost data for the Palmiter technique as compared to alternative erosion control methods, it is noted that the Palmiter method costs are no greater than the costs of traditional methods, but typically lower cost overall. It is noted that one installation, the Nixon Covered Bridge site in Warren County, is omitted from Table 2 because there was very little data and metrics provided for that site.

Table 2: Summary of Key Metrics of Existing Palmiter Installations

	Eleazer Road	Yellow Creek	Clear Creek (Heatherwoode)	Clear Creek (E. Milo Beck)
Project Details:				
• Location	Greene County	Summit County	City of Springboro	City of Springboro
• Use Case	Bridge	Roadway	Channel	Roadway
• Project Length	350 feet	500 feet	4,430 feet	540 feet
• Date of Installation	June 2019	November 2019	October 2018	November 2018
Palmiter Installation Details:				
• Large Trees Installed	≈12	≈15	≈75	≈18
• Total Cost (Full Cost incl. Design)	$49,500	$89,915	$452,320	
• Cost per Large Tree	$4,125	$5,994	$4,864	
• Cost per Linear Foot	$141	$180	$91	
Alternative Erosion Control				
• Project Type	Dump Rock	Trench Fill	Specialty Block Wall	None
• Cost per Foot (Construction Only)	$133	$229	$964	None

Eleazer Road, Caesarscreek Township, Greene County, Ohio

Table 3: Details of Palmiter Installation: Eleazer Road, Greene County

Site Name:	Eleazer Road
Location:	Caesarscreek Township, Greene County
Site Coordinates:	39.56431, -83.878514
Use Case:	Bridge Structure Protection
Project Size:	Narrow stream; channel width 10-15 feet, length 350 feet
Water Body:	Painters Creek
Drainage Area:	7.39 square miles
Problem Description:	Scour and bank erosion on river right portion of bridge structure (see Figure 10).
Project Summary:	Small gravel bar in channel was pushing water toward the structure. Kickers were placed to redirect water toward center of channel and to erode the gravel bar, allowing the channel to migrate away from the problem area. Kickers (≈12 installed) are secured to logs that are buried ≈3-4 feet deep, parallel to the channel, and sunken t-posts (see Figure 11).
Project Date:	June 2019
Prior Work:	Rock installation at bridge location failed to correct issue (visible in Figure 12).
Project Cost:	$ 49,500 total cost. $ 4,125 per large tree installed. $ 141 per foot of stream impacted.
Alternative Cost:	$ 46,700 to fill same area with rock (research team estimate); $133 per foot.

Note evidence of failed rock protection project. Photo Source: Ben Sperry, OU, March 2021

Figure 10: Eleazer Road Installation, Upstream of Bridge Opposite of Installation

Photo Source: Jonathan Viti, OU, March 2021

Figure 11: Eleazer Road Installation, Cables Secured to T-Post

Photo Source: Ben Sperry, OU, March 2021

Figure 12: Eleazer Road Installation, Upstream of Bridge

Yellow Creek at Revere Road, Summit County, Ohio

Table 4: Details of Palmiter Installation: Yellow Creek Road, Summit County

Site Name:	Yellow Creek
Location:	Summit County
Site Coordinates:	41.161274, -81.596387
Use Case:	Roadway Protection
Project Size:	Medium-sized stream; channel width 20-25 feet, problem area length approximately 500 feet; Palmiter project length approximately 3,000 feet
Water Body:	Yellow Creek
Drainage Area:	29.0 square miles
Problem Description:	A tree fell upstream of a bend and caused the bend to erode a road above it on a steep slope, causing enough damage that the county had to close the road.
Project Summary:	Flow kickers (3 total flow kickers constructed from 15 large trees) placed at bend to push water to opposite bank, moving the center of the channel away from the problem area. Trees were planted on bank in 2020 and further planting is planned for 2021 (Figure 15). Sediment build-up inside restoration areas is present. Locals say logs were great fish habitat after installation.
Project Date:	November 2019
Prior Work:	Large retaining wall below road and above the channel on river right. Retaining wall project included trench fill bank stabilization that was unsuccessful.
Project Cost:	$ 89,915 total cost. $ 5,994 per large tree installed. $ 180 per foot of stream impacted.
Alternative Cost:	$ 114,385 for bank stabilization component of roadway repair project (cost provided by Summit County Engineer bid tabulations); $229 per foot.

Photo Source: Jonathan Viti, OU, March 2021

Figure 13: Yellow Creek Installation, Panoramic View

Installation of Flow Kickers Shown. Photo Source: Karel Cubick, MS Consultants, March 2021

Figure 14: Yellow Creek Installation, Facing Downstream

Photo Source: Karel Cubick, MS Consultants, March 2021

Figure 15: Yellow Creek Installation, View from Roadway Facing Downstream

Clear Creek at Heatherwoode Golf Course, Springboro, Ohio

Table 5: Details of Palmiter Installation: Heatherwoode, Springboro

Site Name:	Heatherwoode Golf Course
Location:	City of Springboro, Warren County
Site Coordinates:	39.542011, -84.230702
Use Case:	Channel Protection
Project Size:	Narrow stream; channel width 10-15 feet, length 4,430 feet
Water Body:	Clear Creek
Drainage Area:	29.8 square miles
Problem Description:	Eroding banks at a city-owned golf course needed to be corrected. Erosion also threatened a bridge structure showing signs of scour.
Project Summary:	Kickers were placed at problem areas along the stream as it winds through the course (Figure 8). Project included 11 different installations throughout golf course property affecting 75 large trees and 25 flow kickers constructed. Kickers were obtained on site from trees along bank and existing log jam. Kickers redirect flow to the center of the channel and protect eroding banks.
Project Date:	October 2018
Prior Work:	Retaining wall consisting of specialty concrete block of length ≈409 feet was designed for one section of eroded bank. Not constructed due to high costs.
Project Cost:	$ 452,320 total cost (including second Springboro installation). $ 4,864 per large tree installed. $ 91 per foot of stream impacted.
Alternative Cost:	$ 394,306 for 409-foot retaining wall project in one section (cost provided by City of Springboro bid tabulations); $964 per foot.

Note: Left bank deposition. Photo Source: Jonathan Viti, OU, March 2021

Figure 16: Heatherwoode Installation, Facing Downstream

Photo Source: Jonathan Viti, OU, March 2021

Figure 17: Heatherwoode Installation, Facing Upstream Showing Cable Ties

Note: research team member standing in deposition zone.
Photo Source: Matt Perlik, ODOT.

Figure 18: Heatherwoode Installation, Facing Upstream

Clear Creek at E. Milo Beck Park, Springboro, Ohio

Table 6: Details of Palmiter Installation: E. Milo Beck Park, Springboro

Site Name:	E. Milo Beck Park
Location:	City of Springboro, Warren County
Site Coordinates:	39.54588, -84.261756
Use Case:	Channel Protection
Project Size:	Medium-size stream; channel width 25-30 feet, length 540 feet
Water Body:	Clear Creek
Drainage Area:	43.7 square miles
Problem Description:	An outside bend of the stream was eroding toward West Lower Springboro Road and needed correcting to maintain the road's structural integrity.
Project Summary:	Flow kickers (≈18 total) were placed on the bend to direct flow away from problem area (Figure 19). Significant deposition is present in the installation, you can walk on top of parts of it without sinking.
Project Date:	November 2018
Prior Work:	None
Project Cost:	Included with cost of Heatherwoode installation (Table 5)
Alternative Cost:	None

Photo Source: Jonathan Viti, OU, March 2021

Figure 19: E. Milo Beck Park Installation, Facing Upstream

Little Miami River at Nixon Covered Bridge, Warren County, Ohio

Table 7: Details of Palmiter Installation: Little Miami River, Warren County

Site Name:	Little Miami River
Location:	Waynesville, Warren County
Site Coordinates:	39.497558, -84.102236
Use Case:	Bridge Structure Protection
Project Size:	Large river, width approximately 150 feet; Wild and Scenic designated river
Water Body:	Little Miami River
Drainage Area:	413 square miles
Problem Description:	An outside bend of the river was eroding the river right bank near the Corwin M. Nixon covered bridge and intersecting roadway. Needed to be corrected to maintain the road and bridge's structural integrity.
Project Summary:	Kickers were placed upstream of the bridge to direct flow toward the center of the channel and away from the problem area (Figure 20). Kickers were obtained from trees on site and anchored to stumps and existing trees. Project is notable as being the largest-sized waterway with Palmiter installation.
Project Date:	March 2020
Prior Work:	Routine clearing of logjams by project owner.
Project Cost:	Cost Data Not Available
Alternative Cost:	None

Left: Upstream of Installation; Right: Upstream view with Flow Kicker

Photo Source: Jonathan Viti, OU, March 2021

Figure 20: Little Miami River Installation

APPENDIX C: ODOT HMA SURVEY RESPONSES

As part of Task 7.2 of this project, the research team developed a short five-question survey questionnaire that was designed to collect information about ODOT's current practices for erosion control and stream management. The survey was distributed to Highway Management Administrators (HMA) for five ODOT Districts that were recommended by the Technical Advisory Committee (TAC) for this study. This Appendix presents the verbatim responses supplied by the ODOT District HMA that replied to the research team questionnaire.

Table 8: Stream Maintenance Survey Response, District 3

Q1: In your District, how do you identify sites where erosion control is needed at a bridge or culvert?
A1: Field inspectors report this
Q2: How do you prioritize sites? Do you use the National Bridge Inventory (NBI) or other databases in your decision making
A2: We would search our NBI; immediate concerns are forwarded as priority work orders to the Highway Maintenance Department. Follow-up: what fields of the NBI are consulted in this process? Answer: I have not attempted a search for this, but would search the NBI rating fields 61 Channel and 61.01 Scour for low ratings; I would search the comments also for keywords such as "alignment", "channel protection", "scour", and "hydraulic opening". I would concentrate my efforts on "4"s or below – these having severe undermining or damage. If the number of bridges with this low rating is manageable, I would also look at "5"s – Bank eroded – major damage. Ratings of "6" are generally equated to Satisfactory Condition; the definition in the Inventory is "Bank Slump. Widespread Minor damage." This seems comparable to a "satisfactory" rating and I would not likely give these much consideration given the other more pressing needs of the District's inventory.
Q3: What is your typical method(s) of addressing erosion at a bridge or culvert
A3: Adding Rock Channel Protection
Q4: Do you have sites identified that need maintenance or mitigation to avoid erosional damage of a bridge or culvert in the next 3-5 years? Please identify them
A4: None identified requiring maintenance
Q5: The Palmiter Method allows low impact stream restoration to reduce stream erosion that may threaten bridges or culverts but takes several years to be fully effective. Do you have sites that you have identified that may be good candidates for this type of erosion control? Please identify them
A5: None identified

Table 9: Stream Maintenance Survey Response, District 5

Q1: In your District, how do you identify sites where erosion control is needed at a bridge or culvert?
A1: During the annual bridge inspection or special inspection after a flooding events
Q2: How do you prioritize sites? Do you use the National Bridge Inventory (NBI) or other databases in your decision making
A2: Only if it is an ongoing maintenance issue but most repairs are reactive. The district uses a work order process that is in place at ODOT
Q3: What is your typical method(s) of addressing erosion at a bridge or culvert
A3: Dump rock is the first repair option, but the district has use other method to make repair (sheet pile, concrete, vanes and willows)
Q4: Do you have sites identified that need maintenance or mitigation to avoid erosional damage of a bridge or culvert in the next 3-5 years? Please identify them
A4: The district current has one location it is working on Lic-16-16.56
Q5: The Palmiter Method allows low impact stream restoration to reduce stream erosion that may threaten bridges or culverts but takes several years to be fully effective. Do you have sites that you have identified that may be good candidates for this type of erosion control? Please identify them
A5: The district has used willows for stream restoration on Knox SR13 at the 12.90-mile marker. The other location the district used a vane is on Knox SR229 at the 14.60-mile marker. Also considering using this method at Cos-93-06.46

Table 10: Stream Maintenance Survey Response, District 7

Q1: In your District, how do you identify sites where erosion control is needed at a bridge or culvert?
A1: After reviewing inspection reports and talking to our inspectors who do the reports. If they see anything that they are concerned about they call, email, and document with photos
Q2: How do you prioritize sites? Do you use the National Bridge Inventory (NBI) or other databases in your decision making
A2: We look at the footing types first thing, like spread footings, founded on pilling, rock, etc. We look at the alignment (or migration) of the stream with respect to the footings. We also look at the history of the structure, has there been work there before, or recurring problems with scour and erosion. We also look at what is upstream and downstream. If there are farm fields or wooded areas, how clean the channel is, and bottom material type. We look at land use and elevational gradients of the streams and creeks through the structures
Q3: What is your typical method(s) of addressing erosion at a bridge or culvert
A3: We typically use hard armor (different size rock). It depends sometimes on how easy/difficult the placement. Is it around the end of a pier footing or is up under the deck along the abutment (headroom)? Usually, the easiest method or materials are used first by our maintenance forces. We have our Environmental person involved along the way so that we do not go beyond what is needed and meet environmental permitting requirements
Q4: Do you have sites identified that need maintenance or mitigation to avoid erosional damage of a bridge or culvert in the next 3-5 years? Please identify them
A4: Project PID 110155 (D07-BH-FY24 (A)) with 4 locations (SFN 0601802 AUG-67-17.18), (SFN 1201654 CLA-41-18.48), (SFN 5705428 MOT-70-8.73), (SFN 5706785 MOT-75-6.86 Left
Q5: The Palmiter Method allows low impact stream restoration to reduce stream erosion that may threaten bridges or culverts but takes several years to be fully effective. Do you have sites that you have identified that may be good candidates for this type of erosion control? Please identify them
A5: Detailed list of locations supplied.

Table 11: Stream Maintenance Survey Response, District 8

Q1: In your District, how do you identify sites where erosion control is needed at a bridge or culvert?
A1: The majority are found via scheduled bridge or culvert inspections. There are a few locations that we know to check after major storms
Q2: How do you prioritize sites? Do you use the National Bridge Inventory (NBI) or other databases in your decision making
A2: Issues are typically addressed in the order they are found, but coordination with other programmed projects is also a significant factor. It also depends upon the severity, cost, complexity, in-house crew availability/capability and environmental coordination that is necessary
Q3: What is your typical method(s) of addressing erosion at a bridge or culvert
A3: Depending on size, soil type, velocity, etc. we use methods ranging from placing rock channel protection, using concrete mats such as Fleximat or Armoflex products, gabion baskets, to placing grouted bags around submerged bridge piers
Q4: Do you have sites identified that need maintenance or mitigation to avoid erosional damage of a bridge or culvert in the next 3-5 years? Please identify them
A4: CLE-275-7.71, PID 110554 recently sold and will be repaired this summer along with slide and debris build-up / removal / bridge size culvert repair. HAM-32-0575 is an in-house project being developed in conjunction with an Ohio State Research Project that will install a vane constructed of concrete blacks to mitigate erosion, scour, and debris build-ups. This will hopefully be constructed using in-house forces this summer. PRE-122-17.67- Using concrete blocks as a vane to control stream erosion behind a pier (PID 102767, sells FY2022). GRE-235-1110- Sold project in conjunction with bridge rehab that also includes a vane constructed of blocks and sheetpiling on the Mad River to straighten flow under bridge that has caused significant pier erosion in the past. Will probably be constructed this year. These are just a few that come to mind. As others are discovered or come to mind, we can certainly keep this option in mind and will reach out to you
Q5: The Palmiter Method allows low impact stream restoration to reduce stream erosion that may threaten bridges or culverts but takes several years to be fully effective. Do you have sites that you have identified that may be good candidates for this type of erosion control? Please identify them
A5: We will review this type of need with the County Managers to see if there are locations that come to mind for this type of repair.

Table 12: Stream Maintenance Survey Response, District 10

Q1: In your District, how do you identify sites where erosion control is needed at a bridge or culvert?
A1: We inspect all bridge structures annually. During these inspections would be when we identify erosion/scour issues
Q2: How do you prioritize sites? Do you use the National Bridge Inventory (NBI) or other databases in your decision making
A2: Each of our counties receive maintenance items at the conclusion of bridge inspections in their individual county. They are very diligent at addressing bridge maintenance needs so there is not usually a need to prioritize a list of bridges with erosion/scour. If we find an exceptionally important location we get in contact immediately with that county and they address the issue immediately. We do not really use NBI for the decision making, it is more for simply reporting current conditions. However, I do use NBI inspection reports to verify that there is no outstanding issues that have not been brought to my attention. Scour rating 6 and under is sufficient for identifying scour issues from NBI.
Q3: What is your typical method(s) of addressing erosion at a bridge or culvert
A3: Rock armament is the typical treatment
Q4: Do you have sites identified that need maintenance or mitigation to avoid erosional damage of a bridge or culvert in the next 3-5 years? Please identify them
A4: Erosion/Scour is not an issue that can be scheduled out 3-5 years. When we find issues, they become priority and are corrected immediately. As such, we do not have a list of future corrective work
Q5: The Palmiter Method allows low impact stream restoration to reduce stream erosion that may threaten bridges or culverts but takes several years to be fully effective. Do you have sites that you have identified that may be good candidates for this type of erosion control? Please identify them
A5: With this type of work, the greatest challenge becomes access and R/W. I do have reoccurring problem areas that I would love to address but I really need to find out the specifics on what, when, and how the proposed structures would be built. I think a little more information on your intentions would help in identifying areas to concentrate on. We have structures from 10' culverts to 1000' multi-spans and everything in between. If you could send me a little more defined interest, hopefully we can identify some potential candidates for you.

APPENDIX D: PERMITTING AND REGULATORY REVIEW

Introduction

This summary is specific to the use of the Palmiter method to manage streams near transportation infrastructure. The federal law that protects waters of the United States is the *Clean Water Act* (CWA) specifically, Section 401 granted through the state, Ohio Environmental Protection Agency (OEPA), and Section 404 granted through the federal agencies US Environmental Protection Agency (USEPA) and US Army Corps of Engineers (USACE). The CWA pertains to the discharge of materials to streams/rivers, lakes, and wetlands.

Summary of ODOT Waterway Permits

According to the Ohio Department of Transportation (ODOT) *Waterway Permits Manual*, permitting falls under General permits and Individual permits.

General Permits

General permits include Nationwide Permits (NWPs) and Regional General Permits (RGPs) and are used when pre-approved activities are utilized to conduct the project. The pre-authorized project activities generally have minimal adverse effects on the waters of the U.S., described as less than 0.50 acres of wetlands and less than 300 linear feet of streams. General permits offer a streamlined approach, typically 30 days processing time in comparison to the Individual 401/404 typical process time is 8-12 months. However, if impacts exceed thresholds utilized for General Permits then Individual 401/404 permits are required. Regional General Permits (RGP) are similar to 2017 Nationwide Permits (NWP), but its use is limited to ODOT. RGP is specialized by ODOT and USACE to address typical transportation-related activities for only ODOT-led projects. There are three Regional General Permits: RGP A - linear transportation, RGP B - maintenance of existing transportation infrastructure, and RGP C - bank stabilization, these emulate the 2017 Nationwide Permits 14, 3, and 13, respectively (ODOT 2020c).

Pre-Construction Notification Requirements

Some activities authorized by NWPs and RGP require notification to USACE through the Pre-Construction Notification (PCN) process. These are called "triggers" or PCN thresholds. For example, an NWP 13 bank stabilization project, required PCN for activities greater than 500 linear feet of stream, fills greater than 1 cubic yard per running foot, or discharges of dredged or fill material into a special aquatic site. In addition, all activities with work components in National Wild and Scenic River Systems require PCN (Big and Little Darby, Little Beaver, Little Miami) or designated "study river" (USACE 2019). Table 13 provides typical PCN submittal thresholds. The USACE can authorize the proposed water quality impact to the stream under the NWP 3 and 13 and RGP B and C, the typical permits encountered when utilizing the Palmiter method for stream management (ODOT 2020c and USACE 2019).

Table 13: PCN Thresholds for Commonly-Used ODOT Waterway Permits

Permit	Pre-Construction Notification (PCN) Threshold
NWP 3: Maintenance	
	Removal of accumulated sediments and debris from Section 10 waters in the vicinity (200 feet) of existing structures as described in paragraph (b) of NWP 3
	The use of any permanent vertical bulkhead greater than one foot waterward of the original alignment. A vertical bulkhead is defined as any structure, or fill, with a vertical face. It may be constructed of timber, steel, concrete, etc.
	Activities in Section 10 waters that involve the discharge of greater than 10 cubic yards of dredged and/or fill material below the ordinary high-water mark
	For temporary structures, work, and discharges (including cofferdams) necessary for access fills or dewatering of construction sites occurring in wetlands, perennial streams, or Section 10 waters when the primary activity is otherwise authorized by USACE. The Notification must include a restoration plan showing how all temporary fills and structures will be removed and the area restored to pre-project conditions.
	All activities in the Ohio River and the Muskingum River
	Any stream channel modification that exceeds a distance of 50 feet upstream and 50 feet downstream of the structure
NWP 13: Bank Stabilization	
	The activity is greater than 500 feet in length along the bank
	The activity exceeds an average of one cubic yard per running foot
	The activity discharges dredged or fill material into special aquatic sites.
RGP B: Maintenance	
	Discharge of greater than 25 CY of dredged and/or fill material in a Section 10 water
	Removal of accumulated sediments and debris from Section 10 waters in the vicinity (200 feet) of existing structures as described in paragraph (b) of RGP B
	Use of vertical sheet piling and closed structures in the special habitat waters of Lake Erie
	Maximum length of temporary discharge into stream as measured upstream to downstream exceeds 300 feet
RGP C: Bank Stabilization	
	Greater than 500 feet in length along the bank
	Exceed an average of one cubic yard per running foot along the length of the bank, below the plan of the ordinary high water mark
	Discharges of dredged or fill material into special aquatic sites
	Discharge of greater than 25 cubic yards of dredged and/or fill material and/or fill material below the ordinary high water mark of a Section 10 water
	Activity is located in Lake Erie, Sandusky Bay, or Maumee Bay and involves the discharge of more than 10 cubic yards of dredge and/or fill material below the ordinary high water mark
	Use of any permanent vertical bulkhead in Lake Erie, Sandusky Bay, and Maumee Bay
	Source: ODOT (2020c) and USACE (2019)

Individual Permits

Individual Permits (IP) are needed when more than a minimal adverse effect on the aquatic environment is anticipated. Part of this permit process requires analysis of alternatives to avoid water quality impacts to streams and wetlands. If a 404 IP is required, then an Individual 401 Water Quality Certification from Ohio EPA will also be needed. The 401/404 application are submitted concurrently.

Section 401 of the Clean Water Act requires state agencies to evaluate projects that will result in discharge of dredged or fill materials into waters of the United States to determine whether the discharge will violate the State's water quality standards. Example of these projects include stream rerouting, culverting streams, filling wetlands/lakes. The Ohio EPA requires a physical habitat survey of the stream be submitted with the application, a Qualitative Habitat Evaluation Index (QHEI) for wadable streams and the Headwater Habitat Evaluation Index (HHEI) for headwater streams. As part of the 401 application to address threatened and endangered species, applicants request comments and coordinate with ODNR and USFWS. The response from ODNR and USFWS will determine if a mussel survey or other biological survey are needed (OEPA 2020). For more information, ODNR created an Ohio Mussel Stream list grouping Ohio streams into 5 categories based on stream size and potential presence of federally listed mussel species (ODNR 2020b) and an Ohio's Listed Species document showing wildlife considered to be endangered, threatened, species of concern, or special interest (ODNR 2020a).

Palmiter Method Activities and Waterway Permit Considerations

Summary of Permit Considerations

Table 14 shows a list of permits that are likely to be utilized when implementing stream management and maintenance following the Palmiter method. A detailed description of each of these permits can be found in ODOT's Waterway Permits Manual (ODOT 2020c). Most activities outlined by the Palmiter method will fall under RGP C – Bank Stabilization. For Palmiter method activities that would fall under RGP B: Maintenance, ODOT's *Highway Operations Environmental Checklist* (Appendix D.1) provides a list of allowable activities and activities to avoid (ODOT 2020b). Appendix D.2 provides a summary table of Palmiter activities, PCN requirements, and permit selections. It should be emphasized that the permit type and activities outlined in this Appendix, as well as the associated commentary provided herein, represent the research team's interpretation of the applicable waterway permits.

Table 14: Waterway Permit Types and Palmiter Method Activities

Permit Type	Palmiter Method Activities
Regional General Permit (RGP) B: Maintenance and Nationwide Permit (NWP) 3: Maintenance	Log jam removal, seeding disturbed areas, placement of material to protect bridge structural components, removal of sediment near structures.
Regional General Permit (RGP) C: Bank Stabilization and Nationwide Permit (NWP) 13: Bank Stabilization	Tree revetments, vegetation planting on eroding banks (i.e. willow posting)
Nationwide Permit (NWP) 27: Aquatic Resource Restoration	Removal of accumulated sediments, installation of current deflectors, modification of stream bed and/or bank to enhance, rehabilitate, or reestablish stream meanders
Individual Permit 401/404	Needed if the proposed work requires more than minimal adverse effect to the environment or exceeds general permit thresholds

Details of Permit Considerations

This section presents the details of the regulatory and permitting considerations for each of the phases of the Palmiter method as summarized in Table 14. Witter and Mecklenberg (2019) summarized the types of in water work needed for transportation maintenance fall into 4 categories:

1. Dredging of accumulated sediments from the bridge or culvert opening;
2. Removal of debris accumulations from stream banks and bridge piers near infrastructure;
3. Armoring of stream banks to mitigate erosion; and
4. Placement of materials to protect bridge structural components (e.g. piers, abutments) from scour.

All four of these categories fall within the activities described by the Palmiter method (Herbkersman, 1982). The Palmiter method activities that trigger permit requirements are listed below with a description of the triggering activity and the permitting route to be considered.

1) Log Jam Removal

- a) Removing debris from bridge abutments to allow for flow conveyance authorizes under RGP B
  - i) Any stream channel modification is limited to the minimum necessary for the repair, rehabilitation, or replacement of the structure or fill; such modifications, including the removal of material from the stream channel, must be immediately adjacent to the project or within the boundaries of the structure or fill" (USACE 2019) – RGP B

2) Protect Eroding Banks (Tree Revetments)

- a) RGP C or NWP 13 authorizes stabilization of stream banks by anchoring trees (cut live or harvested from log jam) along the streambank in low energy areas.
  - i) The tree slows the current and allows silt and sand to be deposited along the streambank and within the branches. The deposited material is good fertile good for tree seeds such as cottonwood and sycamore to sprout and grow, hence creating stability along the bank. With time the anchored tree decays and the bank is stabilized with the new tree growth. Choose a tree with more limbs and fine branches, like eastern red cedar and pin oak. The branches are what help to slow the water and allow silt material to accumulate. Choose a tree with a crown diameter 2/3 height of the eroding bank (MDC 2021).

3) Vegetative Stabilization

- a) RGP C or NWP 13 authorize planting of live cutting such as willows, silky dogwood or other native vegetation along the bank/eroding banks.
  - i) A bio-engineering technique utilizing native vegetation to stabilize eroding streambanks. The roots stabilize and hold soil in place while the tops protect the bank from the flowing waters and reduce the stream velocity

near the bank. Live stakes are utilized when dormant with branches trimmed for best survival (Cuyahoga SWCD, 2021).

4) **Sand and Gravel Bar Removal**

   a) RGP B with PCN authorize the excavation of accumulated sediments and debris 200 feet in any direction from bridges and culverted road crossing does not require authorization from the USACE if there is no subsequent discharge of the dredged material into a water of the US, unless the dredging activity occurs in a Section 10 water
   b) Handling the removed sediment, the following apply:
      i) Dispose of sediment at an upland location 200 meters from any streams or potential wetlands. Avoid placing material on a slope, as the material can move and fall into waters of the US
      ii) Quantity of discharged material and volume of area excavated do not exceed 25 cubic yards below the plane of the ordinary high water mark – NWP 18 Minor Discharges
      iii) Placing any amount of fill into streams and wetlands is regulated under Section 404 and requires a permit.
      iv) Replacing fill back into the same water, or any other waters, is a regulated activity under Section 404 and requires a permit. This includes removing and replacing fill with a net amount of zero.
      v) Note: Pushing or moving stream sediments with bulldozer blades or the movement of excavated material from one location to another in waters/wetlands, is prohibited and requires a permit.
   c) Outside of the 200 feet from the bridge/culvert structure, removal of accumulated sediments and/or modifying the stream bed and/or stream bank to enhance, rehabilitate, or reestablish stream meanders then the NWP 27 Aquatic Resource Restoration applies

5) **Riparian Tree Planting Along the Floodplain**

   a) No permit required - Increases biodiversity, shade in the adjacent waterbody, longer term solution to stabilize streambanks with increase root mass, decreases excess nutrient runoff to stream by root absorption.

6) **Obstruction/Dead Tree Removal Along Banks**

   a) No permit required if the removal of the dead/leaning tree does not result in a discharge of material into waters of the US.
      i) As per the Palmiter method when removing dead/leaning trees that pose a potential impact to structures the trunk should remain intact in the bank, just the upper portion of the tree is removed. This allows for the integrity of the bank to remain stable.

7) **Maintenance**

   a) Disturbed areas along the banks should be reseeded to prevent erosion. The seed mix should be of native Ohio species appropriate for that location. No movement of soil should occur.

b) Ongoing maintenance, especially after severe storm events as described #1-6, would follow the authorizing permit or generally fall under RGP B.

Other Regulatory Considerations

Floodplains

"The Office of Environmental Services Ecological Resources and Permits section provides floodplain guidance that is necessary to ensure that transportation projects are in compliance with the National Flood Insurance Program (NFIP) that is administered by the Federal Emergency Management Agency (FEMA)" (ODOT 2020a). All projects need to avoid increasing base flood (100-year flood) elevations to protect lives and impacts from flooding. *ODOT Floodplain Management Guidelines* provides a structured process to ensure actions are following floodplain regulations; National Flood Insurance Program (NFIP) administered by Federal Emergency Management Agency (FEMA) and National Environmental Policy Act (NEPA). The potential impacts of any nature-based approaches or restoration activities being considered should still be evaluated as part of the action and in consideration of the types of impacts outlined in these Guidelines (ODOT 2016).

Tree Removal

The Endangered Species Act provides protection for the Indiana Bat. Under these protections trees in publicly funded projects may not be removed between April 1 and October 31 to prevent the loss of habitat for bats (A. Bonner, personal communication, June 22, 2021). For more information on ways to minimize impacts and conserve Indiana Bat habitat the USFWS provides a guidance document, *Guidance on Developing and Implementing an Indiana Bat Conservation Plan* (USFWS 2011).

In-Stream Work Restrictions

When siting a location for the Palmiter method, it is important to be able to access the work area from either side of the streambank to avoid crossing through the stream. Heavy equipment below the ordinary high-water mark (OHWM) without a causeway or work pad in not allowed under RGP C. If temporary access for instream work is needed, then a Nationwide Permit 33 would apply. If RGP C applies, then temporary impacts, such as a causeway or work pad can be authorized under this permit but generally this is not looked upon favorably by the Army Corps of Engineers (A. Early, personal communication, May 28, 2021).

Mussels

When in-stream impacts cannot be avoided such as discharge of dredged or fill materials, the applicant must consider impact to threatened and endangered species such as freshwater mussels. All native mussels are protected in the State of Ohio as well as ten federally listed species occur in the State and are protected by the Endangered Species Act. Impacts to mussels and their habitat should be avoided. If they can't be avoided, all streams which contain mussels or potential mussel habitat must be surveyed prior to any proposed stream disturbance. Survey index period is typically May 1 – October 1. ODNR provides an Ohio Mussel Survey Protocol updated April 2020 (ODNR 2020b).

Ohio EPA requires applicants to coordinate with Ohio Department of Natural Resources and U.S. Fish and Wildlife service on threatened and endangered species. Adequate documentation confirming the applicant has requested comments from ODNR and USFWS regarding threatened and endangered species including the presence or absence of critical habitat. If the response letter from either of these agencies requires a mussel survey to be done, OEPA requires it be done prior to the issuance of a 401 (R. Taulbee, personal communication, May 4, 2021). Streams are reviewed based in part on stream size and the potential presence of federally listed mussel species (FLS). Ohio streams have been divided into five categories:

1. Unlisted: Streams not listed with watersheds >5 mi^2 with the potential for mussels but FLS not expected.
2. Group 1: Small to mid-sized streams, FLS not expected.
3. Group 2: Small to mid-sized streams, FLS expected.
4. Group 3: Large Rivers, FLS not expected.
5. Group 4: Large Rivers, FLS expected.

ODNR's Mussel Survey Protocol provides an Ohio Mussel Stream List in Appendix A of that document that provides these groups. For Group 1 streams and Unlisted streams with a drainage area greater than 5 square miles, a reconnaissance assessment can be conducted following the Reconnaissance Survey for Unionid Mussel to determine if mussels are present. For all Group 2, 3, and 4 streams at any location within their watershed with a drainage area greater than 5 square miles requires a mussel survey conducted by a qualified surveyor following the ODNR Mussel Survey Protocol (ODNR 2020b).

Conclusion

This summary provides background on typical Palmiter method activities and the associated *Clean Water Act* permitting route to be considered. Many of the Palmiter method stream management activities are anticipated to have minimal impact to waters of the US and will be authorized under the ODOT Regional General Permits B and C. However, given the unique nature of environmental conditions and the scale and needs of each project, projects are evaluated on a case-by-case basis. Special consideration for work in stream and rivers designated as Wild and Scenic Rivers, these requires "Pre-Construction Notification" (PCN) with the USACE. In addition, if the project will result in a discharge or fill material into the stream, coordination with Ohio EPA, ODNR, and USFWS are needed to address freshwater mussels and threatened and endangered species.

It should be emphasized that the permit type and activities outlined in this Appendix, as well as the associated commentary provided herein, represent the research team's interpretation of the applicable waterway permits. Only the regulatory agencies with jurisdiction over a particular resource can provide a specific and conclusive determination of the permits required for the Palmiter method.

Appendix D.1. ODOT Highway Operations Environmental Checklist Guidance

https://www.dot.state.oh.us/Divisions/Planning/Environment/manuals_guidance/Documents/State%20and%20Local%20Funded/Highway%20Operations%20Environmental%20Checklist%20Guidance.pdf

Guidance for In-Water Work with No Temporary Fill (Including Stream and Jurisdictional Ditch Clean-out) (v.3.9.17)

The following summarizes the limitations for 100% state-funded in-water work without temporary fill, including ditch clean out activities in streams and jurisdictional ditches, as ODOT's Office of Environmental Services (OES) currently understands through consultation with the United States Army Corps of Engineers (USACE) and Ohio Environmental Protection Agency (OEPA). Most simple debris removal projects should not require coordination with the resource agencies, and therefore a permit is not required for excavation activities when no fill is proposed. However, before any clean out activity occurs, the District Environmental Coordinator should compare the proposed work to the limitations set out in this guidance and against any restrictions placed on the project. If work is occurring within the Coastal Zone Management Area, and the elevation is at or below the mean elevation of Lake Erie (571 feet) and/or is influenced by the backwater of Lake Erie, coordinate the project with OES-WPU as a Section 10 Letter of Permission or Permit from the USACE may be required.

When work is to remove debris (including sediment) from a waterway, the following conditions must be met for the work to proceed without coordination with OES and the resource agencies:

1. Work Processes
    a. Heavy equipment should not be operated below the ordinary high water mark of the stream except when no other alternative is practicable.
    b. No causeways, dewatering, or access fills are allowed in surface waters to conduct the work;
    c. No equipment or materials should be stored or stockpiled below the OHWM or the floodplain. Doing so will result in an illegal fill;
    d. All staging of equipment and materials should occur in an upland area;
    e. For any work stoppage longer than 2 hours, equipment should not be left/parked/stored/staged below the OHWM or floodplain;
    f. Work should be conducted when the steam is in a low flow condition (typically August to October);
    g. Work of this type should produce no more than incidental fall back of material from excavating equipment is allowed. This includes material that may fall from the tracks/wheels/or bucket of the machinery back into the stream during the work.
    h. Pushing or moving stream sediments with bulldozer blades or the movement of excavated material from one location to another in waters/wetlands, is prohibited;
    i. Areas along the banks and riparian, above the OHWM, disturbed by the work must be re-graded to original contours and seeded with a seed mix of native Ohio species appropriate for that location.
    j. Disturbed areas along the banks should be reseeded to prevent erosion. The seed mix should be of native Ohio species appropriate for that location. No movement of soil should occur.

k. If equipment must be driven/operated below the ordinary high water mark of a stream or jurisdictional ditch, the following precautions must be taken to avoid creating an unauthorized (illegal) fill activity and to minimize unnecessary disturbance to the aquatic environment:

i. Entry and exit to and from the stream should be from a single access point along the bank and within ROW;

ii. Care should be taken to limit the movement of the equipment in the stream to the absolute minimum necessary to access the work area, complete the work, and exit the site. Excessive driving around of equipment within the stream is not allowed. Fording, driving equipment across a stream from one bank to the other, is prohibited. Please note ODOT Supplemental Specification 832.06 restricts fording of rivers and streams;

iii. No more than incidental fall back of material from excavating equipment is allowed. This includes material that may fall from the tracks/wheels/or bucket of the machinery back into the stream during the work.

iv. Equipment should be moved extremely slowly (< 3 mph) to minimize the potential for material to be picked up or pushed by the equipment resulting in an illegal fill activity

2. Material Handling and Disposal

a. Material removed from a stream or jurisdictional ditch must be hauled to an upland disposal site and must not be placed into another stream, ditch, or wetland (temporarily or permanently). If possible, dispose at an upland location 200 meters from any streams or potential wetlands. Avoid placing material on a slope, as the material can move and fall into waters of the US;

b. No more than incidental fall back of material from excavating equipment is allowed;

c. Removed materials must be stabilized to prevent erosion;

d. Soil is not regulated as a waste unless there is knowledge of a spill or release of some type or is comingles with other solid wastes (i.e. litter). If any of those conditions apply, the material needs to be disposed of as the appropriate waste type (hazardous, solid, etc.).

3. If any of the following sensitive areas are present or will be impacted by the work, the work must be coordinated before being undertaken:

a. ODNR Biodiversity Database contains records of T&E species or other unique ecological features in the impact area or they may be impacted by the project.

b. Any proposed work location on a stream where the drainage area for the stream is 10 square miles or greater and/or the stream is listed in Appendix A of the most recent version of the “US Fish and Wildlife Service/Ohio Department of Natural Resources Mussel Protocols” as potentially harboring mussels

c. Work will occur during Ohio Department of Natural Resources in-stream work restriction dates as described in the ODOT Ecological Memorandum of Agreement

d. Work is in, over, or under a Section 9 or 10 waterway.

e. Work is in or within 1,000 feet of a National or State Wild and Scenic River.

Section 404 Regulation: Natural Channel Design Criteria for Regional General Permit B

(Maintenance)

Natural Channel Design is becoming a more common method for maintaining structures where streams deposit a high amount of sediment, causing maintenance crews to clean out the streams more frequently. This guidance is meant to help DECs determine which types of natural channel design projects will meet a non-notifying RGP B. DECs must submit a PDR to OES-WPU for all natural channel design projects.

General Section 404 Principles:

1. Removing fill is not regulated under Section 404.
2. Placing any amount of fill into streams and wetlands is regulated under Section 404 and requires a permit.
3. Removing fill, but replacing fill back into the same water, or any other waters, is a regulated activity under Section 404 and requires a permit.
    a. This includes removing and replacing fill with a net amount of zero.
4. Dewatering a stream does not count as fill within the dewatered area (unless other impacts will occur). However, the device used to dewater (cofferdam, pump, etc.) does count as fill and is considered an impact requiring a permit.
5. Regional General Permit (RGP) B (Maintenance) is authorized for projects associated with the repair, rehabilitation, or replacement of an existing and currently serviceable structure.
    a. Stream channel modification is limited to the minimum necessary for the repair, rehabilitation, or replacement of the structure or fill.
        i. Modifications, like removing material from the stream channel, must be immediately adjacent to the project or within project boundaries of the structure or fill.
    b. Temporary fills must consist of materials, and be placed in a manner, that will not be eroded by expected high flows.
    c. Following completion, temporary fills must be removed in their entirety and affected areas must be revegetated, as appropriate.

Activities permitted under RGP B:
1. Debris removal
2. Cross vanes, rock vanes, j-hook vanes, etc. shall be directly adjacent to the structure with the purpose of protecting the structure
    a. Ex: directing flow to the center of the structure, away from abutments, piers, etc. and reducing stream bank erosion that directly affects the structure
3. Channel stability when the instability is directly affecting the structure
    a. Ex: bank erosion threatens an abutment or pier
    b. Ex: stream migration due to sediment deposition is undermining a wing wall, pier, abutments
    c. Ex: material deposition is creating a floodplain bench that is stressing the bank, and impacting hydraulic capacity and flow the stream, leading to the stream no longer flowing under the bridge as designed
4. Rock channel protection to protect the structure (not solely to protect a bank)
    a. Must be the minimum necessary to protect the structure, and cannot exceed 300 feet from the structure in either direction

5. Temporary activities
    a. Maximum of 2 year duration per single and complete project

Activities *not* permitted under RGP B:
1. Stream realignment/relocation
    a. Does not include removing accumulated sediment
2. Stream channelization
    a. Includes: the manipulation of a stream's course, condition, capacity, or location causing more than a minimal interruption of normal stream processes
        i. Increasing the capacity adjacent to the existing structure in order to protect it from sediment deposition will typically be permitted. Increasing capacity upstream and not adjacent to the structure is not permitted.
    b. Ex: channelization to reduce or negatively impact the capacity of the stream.
3. Stream stabilization
    a. Re-grading and reinforcing stream bank
        i. ex: rock toe, biodegradable coir rolls, and live stake vegetation
    b. Channel maintenance that affects channel characteristics
        i. ex: riffles upstream of a structure; significantly negatively lowering the flow line
    c. Slope protection not directly associated with an existing structure (includes rock channel protection)
4. Stream restoration
    a. Installing riffles
    b. Creating pools
    c. Re-contouring stream bank
    d. Exposing existing riffles (if fill is involved – excavation is not regulated)

Avoid:
1. Projects in Section 10 waters
2. Projects in streams and/or townships with federally endangered species/habitat
3. Projects in a flowage easement of a flood control facility
4. Projects in National or State Wild and Scenic Rivers
5. Projects in Critical Resource Waters or within the Oak Openings
6. Projects that will impact fens, bogs, or other Category 3 wetlands
7. Temporary fill exceeding 300 feet upstream to downstream in perennial and intermittent streams
8. Wetland impacts greater than 0.1 acre
9. Wetland impacts greater than 0.5 acre

Appendix D.2: Summary of Palmiter Activities, Permits, and PCN Requirements

	Pre-Construction Notification (PCN) threshold	Palmiter method activities that could trigger these thresholds	NWP 3 Maintenance	MWP 13 Bank Stabalization	NWP 27 Aquatic Resource Retoration	RGP B Maintenance	RGP C Bank Stabalization	401/404
1	Removal of accumulated sediments and debris from Section 10 waters in the vicinity (200 feet) of existing structures as described in paragraph (b) of NWP 3 and RGP B	Log jam removal, removal of sediment near structures,	X			X		
2	The use of any permanent vertical bulkhead greater than one foot waterward of the original alignment. A vertical bulkhead is defined as any structure, or fill, with a vertical face. It may be constructed of timber, steel, concrete, etc. OR: Use of any permanent vertical bulkhead in Lake Erie, Sandusky Bay, and Maumee Bay	Placement of material to deflect or protect bridge structural components,	X				X	
3	Activities in Section 10 waters that involve the discharge of greater than 10 (NWP) or 25 (RGP) cubic yards of dredged and/or fill material below the ordinary high-water mark OR: Activity is located in Lake Erie, Sandusky Bay, or Maumee Bay and involves the discharge of more than 10 cubic yards of dredge and/or fill material below the ordinary high water mark	Intentional bar and bank erosion	X			X	X	
4	For temporary structures, work, and discharges (including cofferdams) necessary for access fills or dewatering of construction sites occurring in wetlands, perennial streams, or Section 10 waters when the primary activity is otherwise authorized by USACE. The Notification must include a restoration plan showing how all temporary fills and structures will be removed and the area restored to pre-project conditions.		X					
5	All activities in the Ohio River and the Muskingum River	All Palmiter activities	X					

	Pre-Construction Notification (PCN) threshold	Palmiter method activities that could trigger these thresholds	NWP 3 Maintenance	MWP 13 Bank Stabalization	NWP 27 Aquatic Resource Retoration	RGP B Maintenance	RGP C Bank Stabalization	401/404
6	Any stream channel modification that exceeds a distance of 50 feet upstream and 50 feet downstream of the structure	Intentional bar and bank erosion	X					
7	The activity is greater than 500 feet in length along the bank	Kicker Placement, anchor log placement, log jam removal tree revetments, vegetation planting		X			X	
8	The activity exceeds an average of one cubic yard per running foot	Intentional bar and bank erosion		X			X	
9	The activity discharges dredged or fill material into special aquatic sites.	Intentional bar and bank erosion		X			X	
10	Maximum length of temporary discharge into stream as measured upstream to downstream exceeds 300 feet	Repairs of accumulated sediments, installation of current deflectors, modification of stream bed and/or bank to enhance, rehabilitate, or reestablish stream meanders				X		
11	Equipment crossing stream	Removal of accumulated sediments, installation of current deflectors, modification of stream bed and/or bank to enhance, rehabilitate, or reestablish stream meanders			X			X
12	More than a minimal adverse effect on the aquatic environment is anticipated. Part of this permit process will require analysis of alternatives to avoid water quality impacts to streams and wetlands. Coordination with ODNR, OEPA, and USFWS required.	Advanced Palmiter Methods involving the removal of extensive sand bars/sediment, or channel rerouting. These methods are not recommended.						X
13	Activities in Designated National Wild and Scenic Rivers	All Palmiter activities	X	X	X	X	X	X

APPENDIX E: LIFE CYCLE ANALYSIS

This appendix presents an analysis of the various stages of the project life cycle for an erosion control project using the Palmiter technique. For this analysis, the project life cycle includes four stages, presented in order of implementation as follows: 1) site selection; 2) pre-construction planning; 3) construction; and 4) operations and maintenance. For the purposes of this discussion, it is assumed that in-house personnel from the Ohio Department of Transportation (ODOT) will be utilized for all or most of the activities required for the Palmiter technique.

Site Selection

The first phase of the Palmiter project life cycle, Site Selection, focuses on the applicability of the Palmiter technique at a specific site. The research team has identified two use cases for the Palmiter method:

- Advancement of bank erosion toward bridge abutment or culvert due to stream/river flow lines not parallel to bridge or culvert path; and
- Advancement of stream bank erosion and bank retreat leading to undermining of roadway infrastructure.

To identify appropriate sites for erosion control using the Palmiter method, two approaches can be used. The first approach is to identify potential erosion issues as part of on-site inspection of specific bridge, culvert, or roadway locations – either via routine inspection by ODOT personnel or as identified through other on-site work. The second approach is to review inventory databases for bridges and culverts to identify locations with poor scour or other metrics as recorded in the database.

It is noted that these two approaches are quite similar to the current methods used by ODOT to identify erosion-related issues and concerns with its infrastructure. However, the key feature of the Palmiter method is to utilize natural materials to redirect the stream's energy away from problem areas. Based on the research team's observation of sites where the Palmiter method has been implemented, it may be necessary to critically-examine the condition of the stream or river upstream of the problem area (as much as 1,000 feet upstream in some cases) to identify the root cause of erosion issues. Common issues that could be located upstream of a problem area include bank erosion, log jams or fallen trees, and/or sand and gravel bars. A survey of ODOT's current practices indicates that most of the attention for erosion issues is focused on the location of the subject infrastructure; for effective use of the Palmiter method, more detailed examination for issues upstream is necessary. The extent of site review and project area will depend on 1) the location of stream features that are directing flow towards a problematic erosion area and 2) the location where kickers and other woody debris would need to be installed to redirect stream flow away from these areas. For some sites, this will be within ODOT's right of way and in some locations, this will extend beyond ODOT's right of way.

Having identified a location where an erosion control project may be needed, the next step is to determine if the Palmiter method is appropriate for the site-specific problem. The suitability of a specific site for the Palmiter method is based on factors associated with the specific infrastructure to be protected, site-specific conditions, and regulatory concerns present at a specific site. The Palmiter method is not appropriate for structures that are failure-imminent due to the length of time required for the erosion control protection to be fully-effective. Due to the specific construction techniques utilized in the Palmiter method, there are several site-specific nuances that should be examined, as follows:

- Site Access: To effectively repair stream-related issues upstream of the infrastructure location, adequate access to both banks of the waterway should be provided. The project area will include at least the length of stream reach needed to repair issues and an estimated work area of approximately 50 feet set back from the edge of the bank for equipment operations.
- Right-of-Way: It is assumed that some work can take place on existing ODOT right-of-way adjacent to the location of the issue. Because the Palmiter method requires stream bank access upstream of the problem location, it may be necessary for ODOT to acquire the right-of-way needed for the work or secure an easement from the property owner to access the work area. The acquisition activity required is most likely an environmental resource easement or similar in which ODOT would retain an easement for maintenance of the stream channel, but the property owner would retain title to the land itself.
- Availability of Woody Material: The Palmiter method relies on the use of on-site woody material for armoring eroded banks and creating flow "kickers" to direct the stream energy away from problem areas. The availability of woody material should be assessed in the site selection process. Material can be sourced from trees along the bank within the work area, logjams within the waterway in or around the structure, or imported from other project sites.

In addition to the points discussed above, it should be noted that the Palmiter method may not be appropriate for locations where the river channel is greater than 100 feet wide due to the need for trees to be moved between stream banks.

Pre-Construction Planning

The second phase of the Palmiter project life cycle, Pre-Construction Planning, focuses on the specific development activities required to carry out the Palmiter method at a location where it has been determined the method could be successfully used to address an erosion control issue. Pre-construction planning activities include addressing regulatory requirements and design of the project work plan. As noted in Appendix D, it is the opinion of the research team that a majority of the activities required for the Palmiter method will have minimal impact to the waters of the United States and will be authorized under ODOT's Regional General Permits (RGP) B and C. Some instances, as noted in Appendix D, will require Individual Permits (IP), although it is noted that such instances would likely require the IP no matter which erosion control technique is selected. Other regulatory concerns, such as those related to in-stream work (e.g., mussels) and floodplain work restrictions, should be resolved at this stage.

Another important regulatory consideration for the deployment of the Palmiter stream management method is the impacts of tree clearing on the listed bat species of Ohio. In accordance with the programmatic agreements that ODOT has established for bat species, ODOT must determine if suitable wooded habitat (SWH) for the listed bat species is present near project locations. The SWH determination is based on a process established in the programmatic agreement incorporating factors such as the number trees or extent of forested area nearby project sites, location of SWH relative to the roadway, height and diameter of the trees, certain tree features, and the location of trees relative to a riparian zone. Because the Palmiter method relies significantly on woody material sourced at or near waterway problem areas, it is anticipated that an SWH determination will be required for each project where the method is used. It is further noted in the programmatic agreement that potential SWH trees located a distance 100 feet beyond the edge of the roadway are given additional consideration in the ecological survey process. For a Palmiter method project, it is likely that the work area will extend longer than 100 feet past the edge of the highway. For these reasons, it is likely that the Pre-Construction phase for a Palmiter method project will require a review of the site to determine compliance with the programmatic agreements related to listed bat species.

To advance the Pre-Construction Planning phase, ODOT District maintenance personnel should prepare a brief scoping memo including at least the following items:

- Location of the project (e.g., lat/long, highway CRS, waterway name);
- Written description and photos of the erosion control concerns at the site;
- Discussion of the factors contributing to the recommendation of the use of the Palmiter erosion control method; and
- Aerial imagery showing location of issues and ODOT right-of-way boundary.

The research team has prepared a "Site Review and Decision Matrix for Project Planning" document to aid in the site selection and pre-construction scoping process (presented earlier in this report, see Figure 4 and Figure 5). Additional guidance on questions and considerations for completing the "Site Review and Decision Matrix for Project Planning" is presented on the following pages. The guidance includes hydrologic measurements and a thorough assessment of the problematic erosional area and the conditions that are causing it. This will also identify the project length and location in relationship to the ODOT right of way, informing land or right of way acquisition needs. To advance the project into the third phase (Construction), a draft work plan should be developed during the Pre-Construction phase. As noted in the 1982 U.S. Army Corps of Engineers' report on the Palmiter technique, the work plan should diagram the entire project area and indicate the location of problem areas, the proposed corrective actions to be taken by the construction team, and potential sequencing of the work. The draft work plan should indicate the location of trees that are to be removed or topped for use in flow kickers or bank stabilization armoring and the locations where the woody material will be placed to achieve the desired outcomes. Suggestions for symbolizing the various work plan features can be found in Figure 2, Page 30 of the 1982 report and a sample work map is provided in Appendix A of the same report. A modern interpretation of the work plan map as supplied by the Ohio-based vendor of the Palmiter technique (Channel Maintenance Systems) can be viewed in Figure 21.

Palmiter Method Site Review and Decision Matrix for Project Planning:

Site Visit Checklist:

- ✓ Complete This Project Planning Questionnaire
- ✓ Take photographs of entire site
- ✓ Measure length of site, stream depth, estimate bankfull height, location of right of way, etc.
- ✓ Measure stream velocity and/or flow or gather data from nearby USGS gage station (drainage area and peak flows)

Site Characteristics:

1) Is there evidence of bank erosion that will threaten ODOT structures at bridge, culvert, or roadway within the next 2-3 years?

If yes, answer questions a. - h. and continue. If no, Palmiter Method is not applicable.

a. Describe the severity of the scour of bridge or culvert. *This will be useful for project planning and to determine if a) Palmiter is applicable based on the severity, 2) if any intermediary infrastructure stabilization would need to happen prior to a Palmiter method project, and 3) the urgency of the project*

b. Is erosion leading to undermining of a roadway? *This information will inform the project planning and identify problematic erosional areas*

c. Is the main flow of the stream directed at the eroding surface? *This information will inform project planning and the location and orientation of kickers*

d. Is there a depositional area (e.g. sand or gravel bar) forming in opposition to the erosion? *Identified depositional areas in opposition to problematic erosional areas should be identified to inform the redirection of flow to re-align the stream away from a bridge or roadway*

e. Are the eroding banks caused by an obstruction that can be removed? Is a log jam or fallen tree directing the force of the water towards the bank? *This investigation will identify woody debris or other obstructions that should be removed during the project*

f. What is the distance of the eroding banks? Number of meanders within this distance? *This will inform the potential cost and effort of the project and the alternative management approaches and will allow for project planning*

g. Number of log jams/brush piles in the stream within this distance? *This will inform the effort needed to remove problematic jams and brush piles*

h. Does the river have access to the floodplain? *This will inform and define how the river will behave at high flow events when the Palmiter method does most of its work*

2) Is the bridge waterway adequacy large enough to allow for high flows? *The ODOT bridge inventory notes waterway adequacy; if a bridge has inadequate waterway adequacy to carry flow during high flow events, those events are more likely to cause backwaters during high flow events rather than sediment movement upon which the Palmiter method relies* **If yes, continue. If no, Palmiter Method is not applicable.**

3) Is failure of structure imminent? *The Palmiter method takes time to accrue benefits and is not a good fit for imminent failure of a roadway or bridge* **If no, continue. If yes, Palmiter Method is not applicable.**

Site Access and Hydrologic Conditions:

4) Is there safe access, both at the road and in the stream for personnel**?**

If yes, answer a.- d. and continue. If not, Palmiter Method is not applicable.

a. What is the water depth? *Water depth along the worksite area must be shallow enough during the work period for workers to safely wade in chest waders to secure woody debris in the project area*

b. What is the velocity? *High water velocity can lead to unsafe work conditions; water velocities in excess of approximately 2.5 feet/second are difficult to stand, walk, and work safely*

c. What is the drainage area and peak flow? *These data will inform the expected flow conditions at the site; the Palmiter method lets high flow events act to deposit sediment and scour sand and gravel bars, this information will inform the expected hydrologic conditions that will affect the efficacy of the project*

d. What is the bankfull height? *This information will allow project planners to determine the amount of woody debris needed*

5) Is the eroding surface/problem area within the ODOT right of way**? If yes, continue. If no, answer a.** *The Palmiter method addresses the source of the problem, not just the infrastructure. If this full length lies within the ODOT right of way, the project can proceed without further access considerations*

a. Is the upstream landowner willing to grant ODOT access and permission to access the property?

If yes continue. If no, Palmiter Method is not applicable. *The upstream landowner may be willing to give permission or grant a right of way for a project to proceed*

Site Riparian:

6) Is there abundant woody material available on site (i.e. large woody debris in the creek; live trees and brushy material in riparian area)? **If yes, answer a. - d. and continue. If no, answer e.** *The Palmiter method relies upon large and small woody debris to redirect flow, availability of these materials on site can lead to an easier, less expensive project*

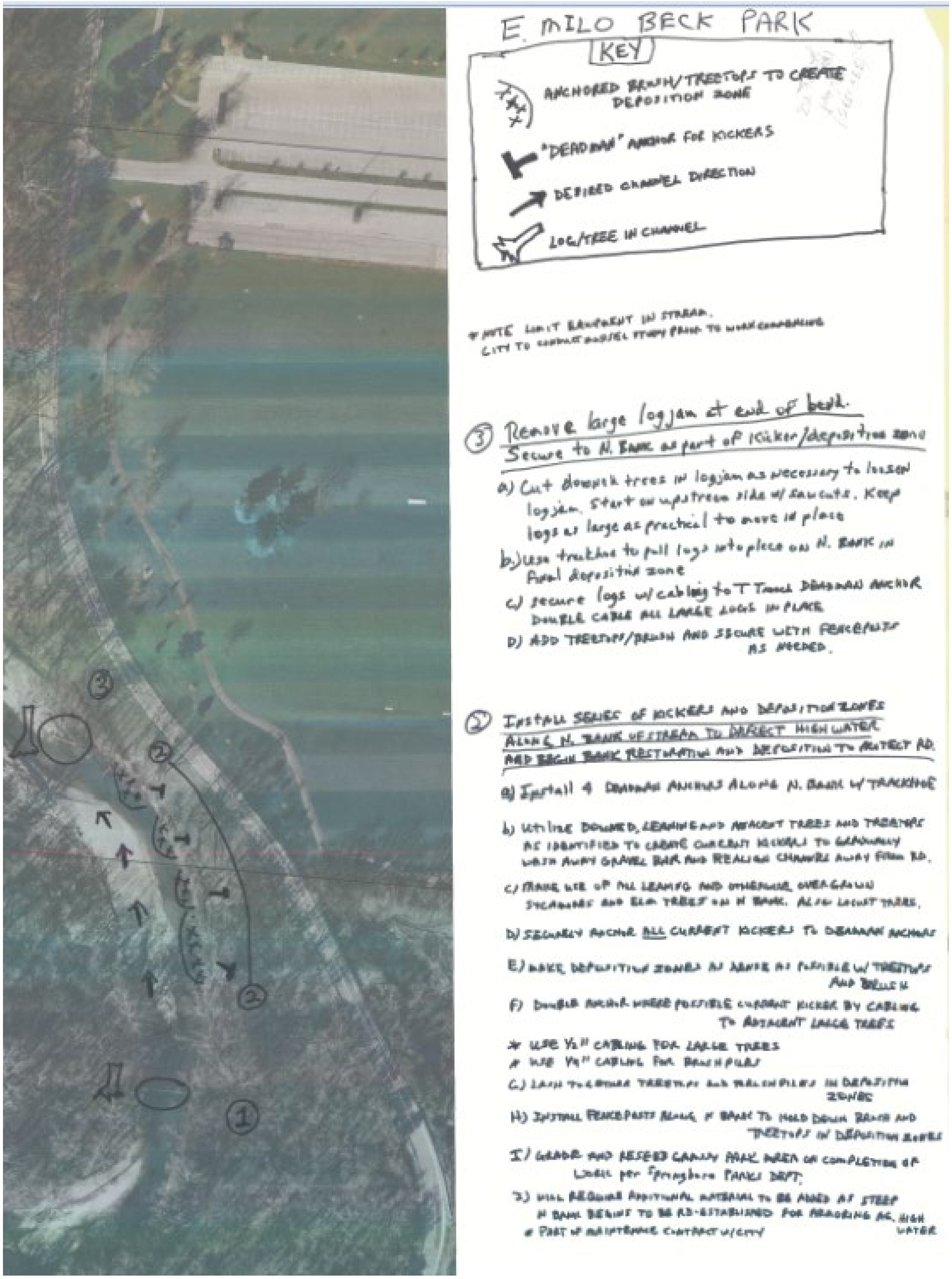
   a. What type of vegetation exists on-site? *This information allows a catalog of available materials for project planning*
   b. What is the maturity/size? *This information allows for project planning*
   c. What are the predominate tree species in the corridor? *This information can inform revegetation efforts*
   d. Are there dead standing trees overhanging the creek? If the trees were to fall, would they contribute to erosion? Do their roots stabilize streambanks? *This information lets project planners select trees to remove and use in the project and identify areas where tree removal will avoid further issues or where trees should be removed to allow a sand and gravel bar to be eroded*
   e. Can woody material be obtained and imported to the site? **If yes, continue. If no, Palmiter Method is not applicable.** *If material isn't available on site, but a nearby roadway clearing project could supply sufficient woody debris, that material may be able to be brought on site to proceed with a Palmiter method project*

Permitting:

7) Is there access on both sides of the stream/river to avoid heavy equipment in the stream**? If yes, continue. If no, answer a.** *Placing large woody debris is best done with a line from a tow truck on the opposite bank and a small excavator on the bank where the work is being conducted. This avoids heavy equipment in the stream which would trigger additional permitting requirements. This method is best conducted where there is access to both banks*

   a. Are freshwater mussels present in the stream? If yes, contact ODNR and USFWS to coordinate guidance on a possible mussel survey and 401-permit application. If no, an ok candidate for Palmiter Method, proceed with permitting process for an NWP 27 and coordinate tree removal during November – March to avoid Indiana Bat roosting April – October. Notify local liveries and municipalities if streams are used for recreation of safety concerns for users.

8) **A good site candidate for Palmiter Method**, proceed with permitting process for RCP C and coordinate tree removal during November – March to avoid Indiana Bat roosting April – October. Notify local liveries and municipalities if streams are used for recreation of safety concerns for users.



Source: Channel Maintenance Systems

Figure 21: Example Work Plan Indicating Location of Construction Activity

Construction

The third phase of the Palmiter project life cycle, Construction, addresses all activities and requirements associated with implementation of the Palmiter method at a project site. The required construction techniques are described in the 1982 U.S. Army Corps of Engineers' report on the Palmiter method. As previously stated, the basic concept of the Palmiter technique is to utilize in-stream materials (e.g., woody plants or other stream bank materials) placed in strategic locations to realign the natural flow of the stream channel. By realigning the flow of the channel, the stream energy moves existing currents away from eroded banks, sand/gravel bars, or other blockages in the channel, with the goal of reducing or eliminating erosion issues that are threatening ODOT's infrastructure. As noted previously, the original description of the technique includes the following steps as noted in Herbkersman (1982):

1. Identification of Erosion Problem Area.
2. Remove Log Jams – Removal of fallen trees and log jams upstream from erosion area to restore the current of the stream to a previous and recent flow path.
3. Protect Eroded Banks – Placement and anchoring of large woody vegetation overlaid with other woody material along eroded banks to prevent further erosion; the vegetation needed for this step can be obtained from the removal of log jams from Step #2 and other locations (Step #6).
4. Remove Sand and Gravel Bars – Where significant sand and gravel bars exist, they are removed by installing current deflectors or by digging pilot channels.
5. Revegetation – Reestablishment of appropriate vegetation to provide additional long-term bank protection and to provide shade for the river and its wildlife.
6. Remove Potential Obstructions – Removal of large trees that have fallen or otherwise obstruct the natural flow of the stream channel, as well as removal of trees in areas where erosion is desired to accomplish the project goals.
7. Maintenance – Periodic reexamination of the state of the stream channel to determine if the outcomes are being achieved or if any new work is needed.

The construction phase addresses steps #2 through #6 from the list above. The typical sequence of construction is to first remove log jams (#2) and other obstructions (#6), then to install bank armoring to protect eroded banks (#3) and flow kickers to redirect stream energy towards the desired path (#4). Digging pilot channels (#4) is done where needed; however, no Palmiter installations viewed by the research team required pilot channels be dug. Due to the permitting implications of digging in the channel, this step is not recommended for ODOT applications. Revegetation (#5) can be done if desired or it may occur naturally as sediment builds up and creates new stream banks. The key element of the Palmiter method is the use of large logs and downed trees to create armoring for eroded banks and "flow kickers" to redirect the stream flow towards the desired path. To aid in stability and to promote buildup of sediment, smaller branches and brushy debris are secured to larger logs or downed trees using rope or cable. The entire assembly is then secured to the bank by anchoring to sturdy trees on the bank or using a "dead man" anchor buried in the ground along the bank. A concept sketch showing the key design features of the erosion protection and flow kicker is presented in Figure 22 with a description of the design notes provided in Figure 23.

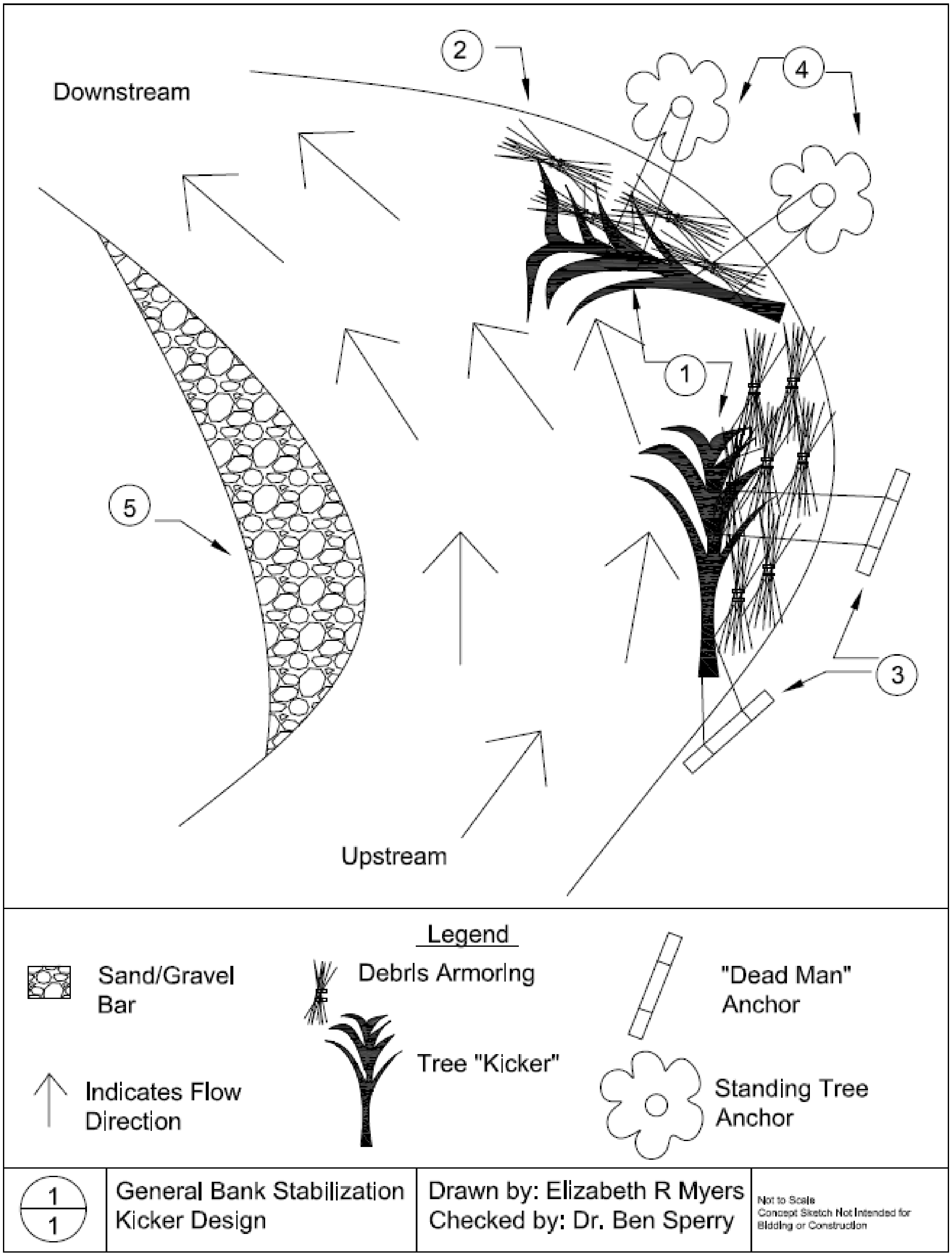


Figure 22: Concept Sketch of Palmiter Method Installation

General Notes for Concept Sketch

Note #1: Large trees should be used for bank armoring or flow kickers as prescribed by the work plan. Large trees shall be a minimum diameter of 10-12 inches and a minimum length of 25-30 feet. Large trees should be sourced from at or near the project site if possible. Trees shall be placed directly against the bank for bank armoring or at an angle between 20 and 40 degrees with respect to the edge of the stream bank to realign flow, as prescribed by the work plan. Tree tops may be retained if desired to retain further sediment.

Note #2: Woody debris rafts shall be constructed using small trees, branches, or other woody material available on-site. The purpose of the debris rafts is to help secure the placement of the larger tree and to promote buildup of sediment to aid in bank restoration. Material shall be securely attached using high-quality rope (Notch Dryad or equivalent) and the entire assembly secured to the large trees using the same type of rope.

Note #3: Large trees may be secured to the bank using a dead man style anchor. The dead man anchor is constructed by attaching the large trees to a shorter log (approximately 6 feet in length) that is buried along the bank at a depth of approximately 6 to 8 feet below ground level. This method of anchoring is preferred where no sturdy trees exist along the bank for tying off (see Note #4 below). See example below, left (photo courtesy of Ron Wine).

Note #4: Large trees may be secured to the bank using high-quality rope and tied off around a large standing tree that is near the bank. Attach only to healthy trees that are not used for any other purpose in construction. Diameter of the bank tree shall be at least the same diamter as the tree used for in-stream installation. See example below, right (research team photo).

Note #5: Indicates location of sand or gravel bar buildup on stream bank. Proper installation of the Palmiter method elements will promote erosion at this location and reshaping of the channel using stream energy. Where applicable, large and small woody debris may be preferentially sourced from this area to further encourage erosion of sand and gravel bars to redirect flow.

Figure 23: Detail Notes to Accompany Figure 22 Concept Sketch

The Palmiter techniques were originally intended to be carried out using human labor or readily-available hand tools rather than sophisticated construction equipment. However, the Ohio-based vendor of the Palmiter method (Channel Maintenance Systems) reported that the use of machinery to aid in tree cutting, relocation and removal of woody materials, and excavation of trenches for "dead man" anchors has greatly improved the efficiency of the construction. In particular, a small backhoe-loader for minor excavation and a tow truck for pulling large trees efficiently have been used by the vendor. Additionally, the vendor reports that a specific brand of high-quality rope (Notch Dryad) is superior to other rope or cable options for securing woody debris together and anchoring.

As noted elsewhere, it is the intent of this project to analyze the feasibility of ODOT utilizing the Palmiter method for its erosion control projects utilizing in-house resources for the labor (i.e., county garage maintenance crews) and equipment needs. A critical analysis of the feasibility of in-house implementation addresses labor requirements, equipment needs, and time requirements for a Palmiter method project. Regarding the labor requirements, it is anticipated that a crew of 3-4 laborers with a supervisor would be needed to carry out an erosion control project using the Palmiter method. A skilled equipment operator would also be needed to operate any equipment that would be required. The work crew would need to be trained on the specific techniques of the Palmiter method by an individual with experience in the method. In addition to training on the specific construction techniques, safety training for work with chain saws and work in/around waterways would be required for the crew. Equipment requirements for the Palmiter method construction include chain saws, a small backhoe-loader with grapple attachment for moving woody material, and a dump truck, work truck, or tow truck to haul away excess material. It is anticipated that the equipment required to carry out the Palmiter method is reasonably available at ODOT's county garages or could be shared among several garages if needed.

Regarding the time requirements, the duration of the construction will be based on the extent of the erosion control activity and the productivity rate of the work crew. It is assumed that the primary unit of work for the Palmiter method is the bank armoring or flow kicker assembly consisting of a single large tree or log attached to the bank via tree or "dead man" anchor, with small branches and woody debris used for stability and sedimentation as appropriate. The work required to assemble a single unit includes preparation of the large log/tree (cut down or import), attach woody debris as needed, placement in the stream according to the work plan, and securing to the bank. Based on experiences from existing Palmiter installations in Ohio, the average construction time is approximately 3 to 5 days using a trained work crew with an average of between 2 and 4 bank armor or flow kickers installed per day. As ODOT crews gain more experience with the techniques of the Palmiter method, the efficiency of the construction activities will increase to optimal levels.

Operations and Maintenance

The fourth and final phase of the Palmiter project life cycle, Operations and Maintenance, incorporates all post-construction activities required to ensure the success of the installation including operational matters and routine maintenance.

Regarding the "operations" of the Palmiter installation, the primary concern is how the installation will impact users of the river (e.g., boaters or waders) as well as recreational users of the bank area (e.g., fishing or enjoyment of the setting). With respect to river users, there may be some short-term impacts post-construction as the trees and other installation features are in the early stages of the sedimentation process. There is the potential for deliberate or inadvertent vandalism or destruction of the installation if there is no obvious indication that the features are placed to help correct erosional issues in the area. As the sedimentation starts to build up in the desired areas within 1 to 3 years of installation, bank users (e.g., fishing) may encounter soft or uneven ground which could be hazardous if the conditions are not obvious to the user. In the long-term, if the installation works as it is designed, there should be limited or no evidence that the installation was ever there and thus most in-stream hazards are limited. To mitigate concerns about the impacts of the Palmiter installation on river users, it is recommended that ODOT install signage in the vicinity of the installation advising that the trees and woody material are deliberately placed, and that the installation should not be disturbed. Additionally, ODOT may wish to coordinate with local park districts, canoe liveries, or other organizations that have interests in the river to inform those groups of the installation and to ensure that these stakeholders do not disturb the installation.

One of the most important steps required to ensure the long-term success of the Palmiter method for erosion control is routine maintenance of the installation and its key features by the project owner. The Ohio-based vendor of the Palmiter method (Channel Maintenance Systems) reports that, for an average project, a secondary maintenance effort is required post-construction to verify that the initial installation performed according to the work plan. The post-construction maintenance has a duration of 1 to 3 days, on average, and takes place after the annual spring flooding or similar high-water event at the project site. Post-construction maintenance activities focus primarily on adjustments to the initial installation to verify the alignment of the key installation elements (bank armor and flow kickers) and repair any issues, such as to reinstall woody debris or brush that breaks loose. For planning purposes, it is anticipated that site inspection of Palmiter installations be planned on an annual basis for at least 3 to 5 years following initial installation, with the inspection to take place following annual spring flooding or similar high-water events. A one-day work session may be needed to carry out any follow-up maintenance or corrective actions at a site, particularly in the early years following construction.