

健康的港口未来：
重新审视河口景观沉积物
Healthy Port Futures:
Rethinking Sediments for Rivermouth Landscapes

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摘要

在整个五大湖地区，港口城市往往位于河口区域。河口曾经将河流沉积物分拣、塑形，并运输到湖中，如今被用作工业航道，需要定期进行机械疏浚维护工作。以往的沉积物管理实践要么将近岸的河流沉积物封存在封闭式处理设施（CDF）中，要么释放于更深的开放水域。这两种处理方式都从近岸系统中清除沉积物，使得其无法在岸线保护、栖息地营造、波能削减和填沙护滩等方面发挥潜在用途。综合上述两种封闭式（如封存于CDF）和低成本开放式（释放于开放水域）的处理方式，新型河口湿地得出了处理和运用沉积物的策略。本文描述了由五大湖保护基金支持的“健康的港口未来”项目所进行的一项尝试。通过协作设计和研究，本项目使用了系列工具集来生成、推测、建模、可视化和测试多个不同社会、生态和水文条件下的湿地形态。该项目可以被形象地称作“月牙”，它提出了一种半圆形、部分开放的单元式湿地设计，以应对河口环境的复杂性。在整个设计－研究过程中，项目试图接纳不确定性、评估风险并探索相应结果，以重新定义公众对湿地营造和修复的期望，并重新构想五大湖沿岸的新面貌。

关键词

河口；沉积物；疏浚；湿地；五大湖区域；设计结合研究

ABSTRACT

Throughout the Great Lakes, port cities are often located on the rivermouth and where rivermouths once sorted, shaped, and moved the riverine sediment into the lake. Their current use as industrial navigation channels requires cyclical mechanical maintenance dredging. Past sediment management practices have either placed the riverine sediment nearshore in confined disposal facilities (CDFs) or out in deeper open water. Both practices remove the sediment from the nearshore system, preventing its potential use in coastal protection, habitat creation, wave attenuation, and sediment nourishment. However, novel rivermouth wetlands can draw from both strategies of containment (as in a CDF) and cost-efficiency of non-containment (open lake disposal) to allow for the processing and use of sediment. This article will describe one such attempt, conducted by the Great Lakes Protection Fund-supported Healthy Port Futures project. Through a collaborative design-research process, Healthy Port Futures used a range of tools to generate, speculate, model, visualize, and test wetland forms under a range of social, ecological, and hydrological conditions. This project, understood colloquially as “the Crescent,” proposed a semi-circular, partially open-cell wetland design as a response to the complexity of rivermouth conditions. Throughout this design-research process, the project sought to acknowledge uncertainty, assess risk, and explore a range of outcomes in order to redefine the public expectations around wetland creation and restoration, and reimagine innovation along the Great Lakes coast.

KEYWORDS

Rivermouth; Sediment; Dredging; Wetlands; Great Lakes; Design Research

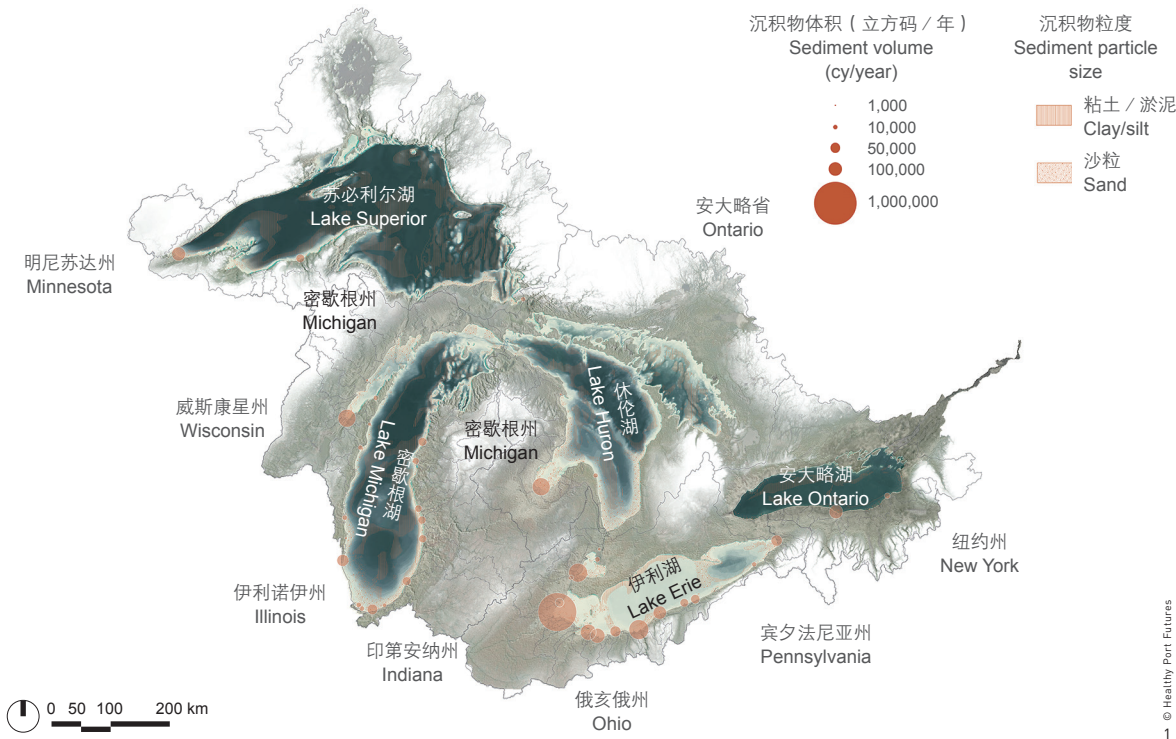
1 背景与问题

河口景观是北美五大湖最重要、或许也是最具冲突性的景观类型之一。这些边缘土地对当地生态、水文和经济的健康发展至关重要，但通常呈现为不同甚至是相互冲突的形式^[1]。19~20世纪河口开发和工业化带来的影响正在展露全貌。如果没有一个机能健康的河口沉积过程，宝贵的栖息地将走向衰败，整个五大湖地区也会被迫受到损害，包括大规模湿地流失、岸线侵蚀、水质恶化，以及贫瘠湖滩的持续萎缩。发生在河湖过渡区的沉积物拣选过程是河口的关键功能之一，但这一过程也尤其容易受到影响。变化无常的水流与浪潮在河湖交界处对沉积物进行拣选、转移、塑形和运输。反而言之，沉积物对于塑造和维护当地生物赖以生存的沿湖栖息地也十分重要。当随着水流流至下游更为平坦的土地，沉积物的流速也慢慢减缓。这里的拣选过程是指，将大颗的沙粒和鹅卵石留在上游，而更为细腻的沙粒、淤泥和粘土则继续向下游流去，投入面积更大、流速更慢的湖水的怀抱^①（图1）。

在整个流域中，许多河口都已经被港口所取代。这些港口景观最后都被限定为简单高效的船运航道。在这个过程中，河湖岸被硬化，蜿蜒流转的河道被裁弯取直、向下深挖，河口被保护起来以免受浪潮侵蚀。由此，那些依赖于沉积物的湖体冲刷和转移的重要过程也会不可避免地受到影响。尽管耗财费力且重复乏味，持续管理这些重要的沉积物对于维护河口的工业功能是不可或缺的。

由五大湖保护基金会资助的“健康的港口未来”（HPF）项目^②旨在与市、州和联邦机构合作，通过对沉积物进行创新性设计来帮助五大湖塑造湖岸韧性。正如提案名称所传达的，HPF项目强调，对这处珍贵的沿湖景观的沉积物进行管理不仅可以避免湖岸线遭到破坏，更可以助推社会和生态的健康发展。基于疏浚研究团队所做的基础工作，HPF项目开展了一系列创新性工作，或为曾经饱受争议的沉积废弃物正名，或利用这一材料进行设计。沉积物是恢复河口原生生态环境的基本元素，重新审

① “尤尔斯特隆曲线”可以清晰地定义并很好地解释这一过程。该曲线确定了颗粒大小和速度之间的关系，并描述了相应的侵蚀或沉积结果。
② 了解关于HPF项目的更多信息，请登录“健康的港口未来”项目官网及五大湖保护基金会官方网站。



1. 五大湖流域。这里综合了得天独厚的地理、生态、文化和经济因素。
1. Great Lakes Basin. This area is a collection of unique geological, ecological, cultural, and economic factors.

视并认识它的形成与消亡过程具有重要意义。

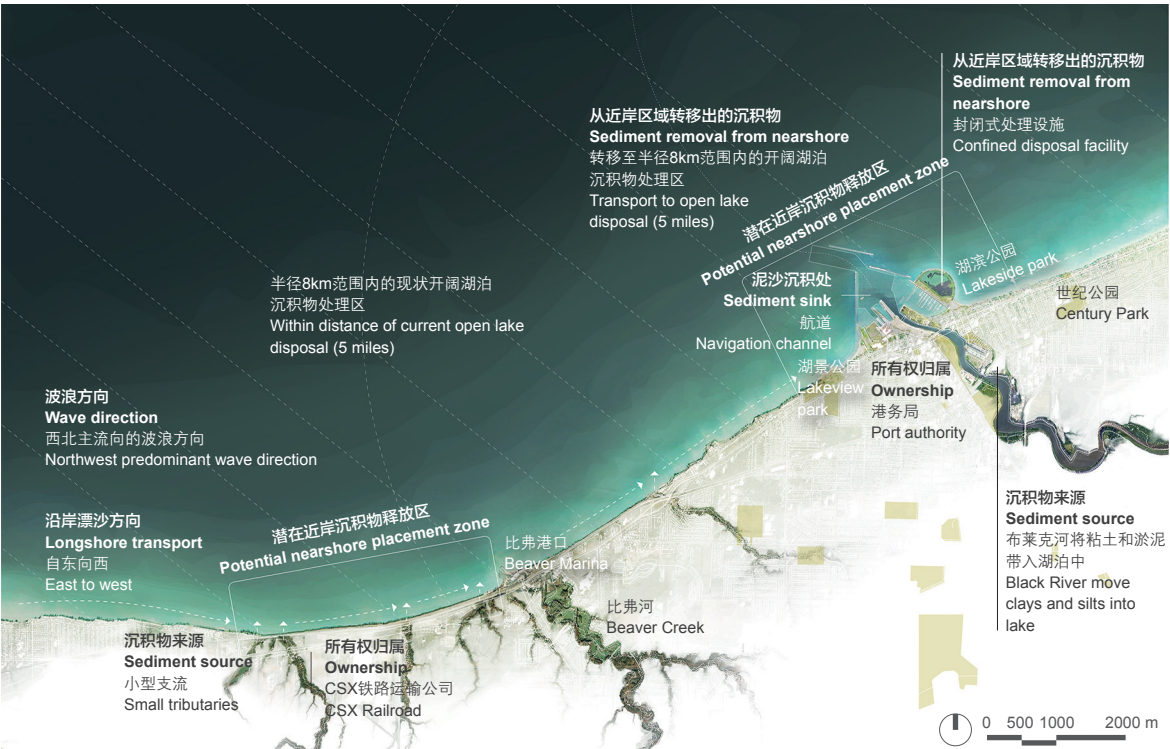
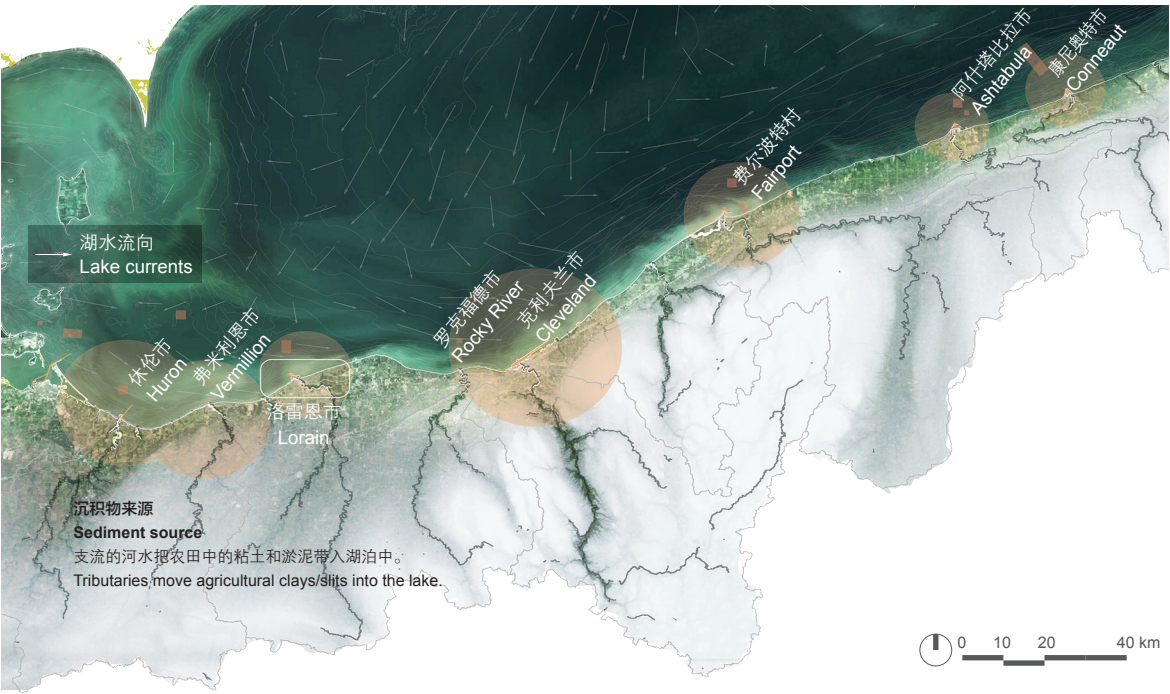
HPF项目聚焦于俄亥俄州河口暨港口城市洛雷恩市。该市位于伊利湖中央流域克利夫兰市以西48km（图2），曾经是一座繁荣的河口城市，然而，像许多五大湖地区的港口城镇一样，凋败的产业迫使河岸景观不可逆转地走向破落（图3）。现状湖岸线记录了人类介入改造的痕迹——不论曾经作何用途，如今都已成为承载休闲娱乐活动的场所。然而，洛雷恩市旧时富饶的沿湖湿地和沙滩却已消失不再。

五大湖本身波动的水文条件和大范围的时空扰动为沿岸湿地建设提供了生态基础。波动的水位通过改变沉积物运输过程来影响特定地点的净侵蚀量和净沉积量。高水位时期，暴风浪侵蚀湖底基质，同时将无机沉积物运送至之前无法到达的区域。低水位时期，则通过沿岸漂沙沉积。沉积物的消长塑造了颇具韧性的湿地，使其能够在受到干扰后进行自我调节。在这里，生物群落已然适应了这种独特的环境条件。而且，高度不稳定和不确定的水文环境往往能增强生态健康。通过抑制优势种、促进植

被演替，以及塑造多样的植被结构和沉积物结构，能够提升栖息地的韧性和复杂性^[2]。这种多样性又反过来助益底栖无脊椎动物、鱼类、水禽等不同生物群落的健康生长^[2]。

然而，虽然湿地已经很好地适应了大范围的自然干扰，但尚难以招架人类干扰，因而造成了大面积的湿地流失。历史地图显示，自20世纪初至今，湖岸沿线水深增加了约2m，原本柔软的湖底被层层剥去，最终湖底仅留有一片压实的坚硬粘土层。鱼类栖居、湿地遍布的广阔沙洲在过去削弱了湖浪的冲刷，保护了高地上的家园，而如今却已消失不见。没有了缓冲地带，洛雷恩市的近岸只得直面高强度的波浪反射，任由大浪撞击硬质化的湖岸线。湿地流失、岸线侵蚀和紧随其后的近岸硬化，导致洛雷恩市的湖岸线长期面临着沉积物流失和移位的问题（图4）。

若要在整个五大湖区域的尺度上进行沉积物处理和湿地修复，就需要进一步提出低成本、低维护的创新性方法。与其他港口城市相似，在洛雷恩市，沉积物要么被密封在封闭式处置设施中^[3]，要么



- 伊利湖中央流域。这些位于中央流域的中型港口城市地处曾经被淹没的河口区域，它们的沉积物管理规划面临相似的机会与挑战。
- 俄亥俄州洛雷恩市的湖岸线。在某基于204条法案的湿地建设项目中，利益相关方发现了近岸区域的潜在价值。
- Central basin, Lake Erie. The mid-sized port cities of the central basin are located in historically drowned rivermouths, and are faced with similar challenges and opportunities in their sediment management plans.
- Coastline of Lorain, Ohio. Selected for a 204 wetland creation project, stakeholders found potential in nearshore.

被转移至开阔的深水域，将其彻底清除，导致它们无从发挥自身在岸线保护、栖息地营造、削减波能和填沙护滩方面的重要价值。在本项目中，长久以来被视为废弃品的沉积物被发掘出新的价值，成为重建沿湖栖息地的重要材料。虽然传统的密封或直接倾倒的处理方法存在诸多问题，但前者的保护作用和后者的低廉成本能够启发一种创新性实践。本文所介绍的试点项目将拓展现有知识边界，试验具有广泛应用前景的新技术。

2 设计过程

洛雷恩市对湿地再利用和建造的有益尝试由俄亥俄州环境保护署（OEPA）和美国陆军工程兵团（USACE）布法罗市分部牵头，因此，需要兼顾解决USACE关注的航道问题和OEPA关注的生态问题。HPF项目团队从可行性研究阶段开始介入，参与选址、与公共利益相关方沟通协调，以及设计理念构建环节，从而在多个利益相关方的目标和评价标准间建立连接。

负责监管疏浚、运输和沉积物处理工作的USACE就项目建设提出了具体要求：人工湿地栖息地应具有一定的持久性，能够在至少50年内保持建成效果，这就需要营造支持其建成并长期存在的环境条件；此外，亦期望湿地仅依靠最低维护就可以维持自身的可持续发展。

OEPA的目标类似但更具生态动机：一系列大有助益的再利用项目为俄亥俄州探索沿岸湿地重建，并恢复其生态功能的区域性创新途径提供了机遇。重建的高品质湿地将容纳多种多样的本土动植物在此繁衍生息。

市政府和社区利益相关方期望将湿地与城市社会经济健康发展相关联。湿地能够承载并进一步激发俄亥俄州沿岸已初见规模的娱乐性活动，这些新建的栖息地可以更好地服务于钓鱼、划皮划艇、冲浪和观鸟的游客。此外，随着岸线侵蚀的治理成本越发高昂，沿湖土地所有者不免为岸线后移而忧心。由于离岸构筑物 and 湿地可以在局部区域削弱波能、保护岸线，因此以保护重要沿岸市政基础设施为目标为其选址。最后，湿地还可以为近岸区域积累额外的沉积物，从而缓解部分在其自身范围以外发生的侵蚀效应。

与管理机构、承包商和社区利益相关方展开协作对于项目的开展至关重要。项目前期，这些利

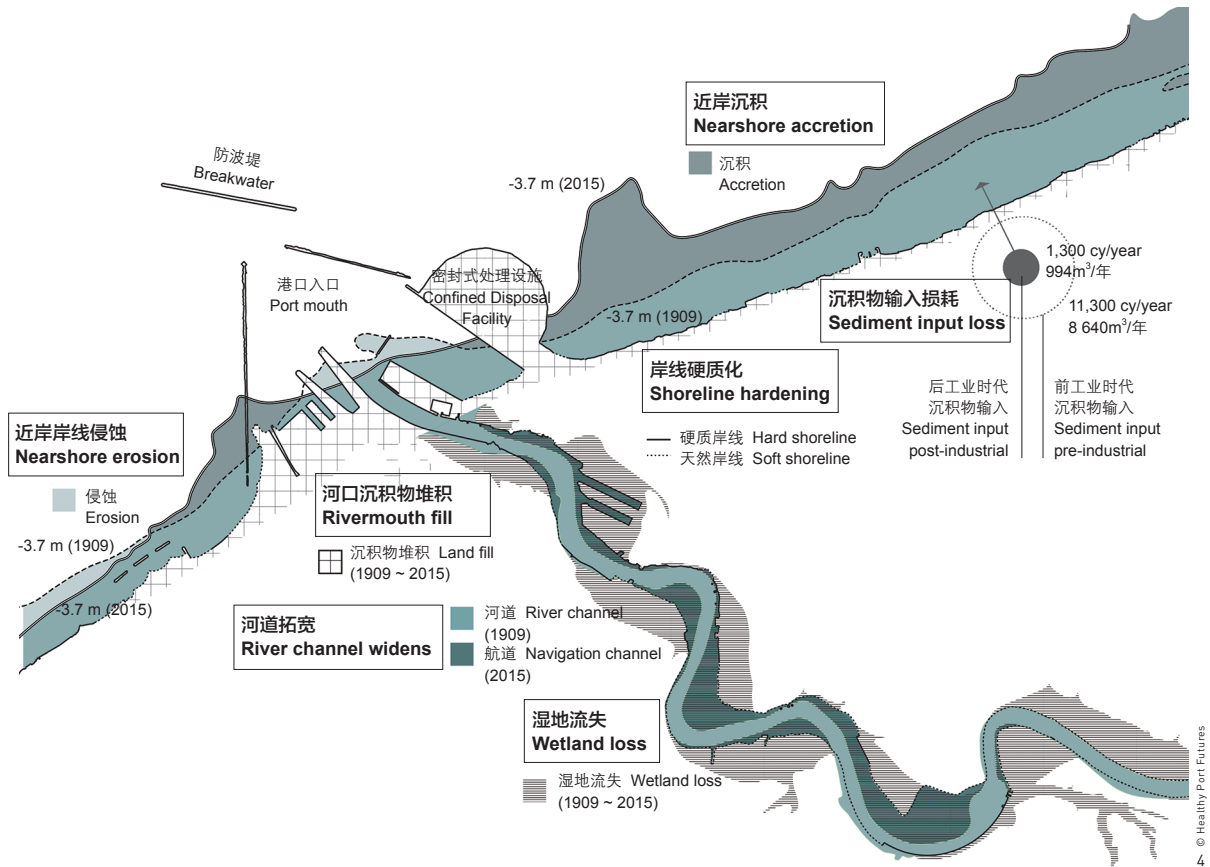
益相关方就沿湖湿地网络营造达成了共识，有效促进了对有关法规的理解。而如何在满足法规要求和社区需求的前提下，通过处理沉积物来实现这一愿景，需要OEPA和USACE的管理者与生态学家们的共同协作。通过协作，法规不再是实现集体愿景的阻碍，反而可以成为一种可借助的途径。

2.1 设计方案

项目执行过程中，HPF项目团队重点关注于恢复河口湿地处理沉积物的基础功能。团队设想通过新型人工湿地来帮助分拣、转移和利用沉积物。这个过程将把USACE使用的机械力与波浪和水流的自然力相叠加。沉积物首先通过机械方式被运送至指定地点，再由湿地中的波浪和水流进行疏浚、收集和分拣。由此，河流沉积物将重归近岸生态系统，用于营造河口湿地、滋养近岸环境和构建湖滩，进而帮助缓解河口工业化带来的诸多问题。

为了创建一个兼具水文与地理连通性的湿地，HPF项目团队构思了一个半开放湿地设计方案（图5），通过混合处理方式在抵挡浪潮冲击的同时保持与湖泊的连通性，但这往往需要能够维护沿湖湿地健康的具有冲突性的环境条件作为前提：湖边的构筑物将为湿地的营造提供必要的防波保护，同时也能抵挡偶尔发生的随机干扰事件。该系统专门利用波浪和水流来创造生态复杂性并保持生物多样性。湖岸的开放结构将提升与近岸地区之间的关键水文连通性和生态连接度，同时，漂流到此的沉积物既可以进入湿地单元，也可流失到环境中，从而实现其在近岸地带的重新分布。半开放湿地并不是坚不可摧、永久存在或孤立的，而应当兼具渗透性、动态性和连通性等密切相关的特征。

从本质上来讲，在近岸的半开放系统中释放沉积物，无论是在时间还是空间上都显著不同于现下十分不提倡的将沉积物疏浚至开放深水水域的做法。这种近岸的半开放湿地模拟了河口机制。平时，浪潮慢慢将较小的悬浮沉积物滤出；偶发的风暴潮事件则会造成更大的冲击，例如引发体积较大的沉积物被冲离湿地结构单元或在其中进行重新组织。不同于上述自然过程，开放水域中的沉积物处理严格按照疏浚日程计划进行。此外，湿地系统也为沉积物匮乏的近岸地区提供了养料补充——这也是河口自然系统中河流沉积物通常的归宿。释放于开放湖泊中的沉积物并不会带来这种额外的生态效益，反而会成为外来粘土和淤泥干扰重要的湖底栖息地。



4. 河口变迁示意图。从历史地图上可以发现，工业化使洛雷恩市的河口区域发生了重大转变，包括河道拓宽及加深挖、湿地流失、岸线硬化和沉积物损失。

4. Rivermouth Changes. Based on historical maps, Lorain has undergone several critical changes, including river channel widening and deepening, wetland loss, shoreline hardening, and sediment loss, resulted from the industrialization of its rivermouth.

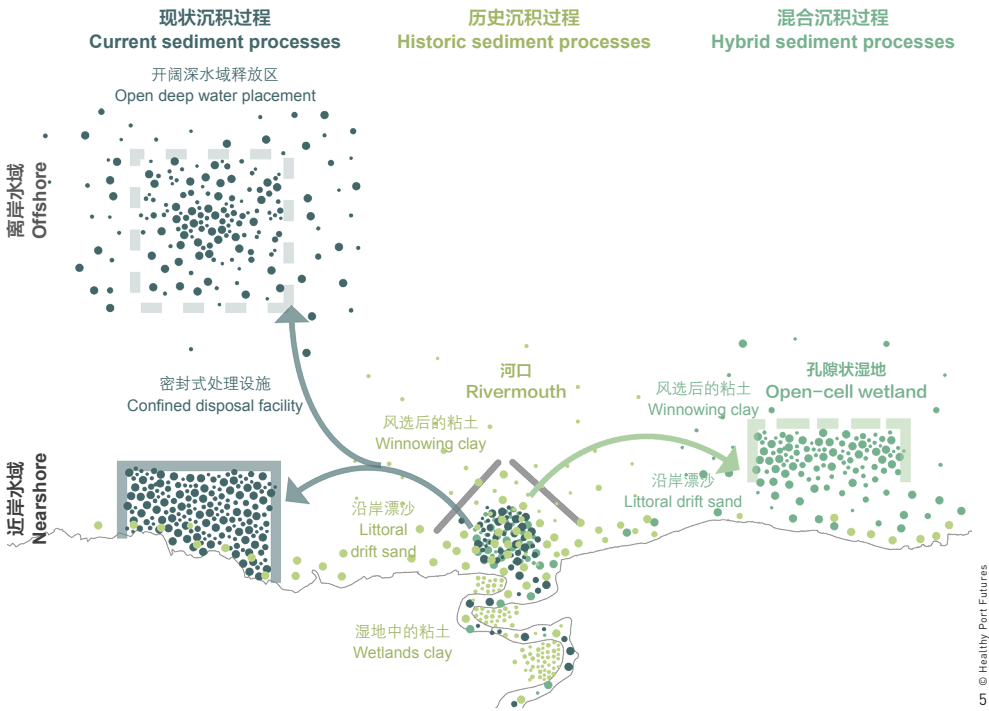
2.2 场地选址

基于HPF项目团队所做的背景调查，依从利益相关方的诉求，最终选定了洛雷恩市的湖岸沿线进行详细研究和探索（图6）。依据靠近航道、既有防波措施、公共所有权，以及具备娱乐和 / 或生态基础设施等对于利益相关方具有重要意义的特定特征，选定了一些场地。尽管彼此之间确有相似之处，但它们代表了多种多样的沿湖港口景观类型。第一个场地位于洛雷恩市航道西侧几英里处，是一条紧邻铁路护坡的绵长湖岸线，这为项目提供了更加自由的实验机会。其余三个场地都位于航道附近，因此受到防波堤的保护、拥有较短的运输距离，且面向公众开放。HPF项目团队将通过更详细的研究，以选定的各场地来代表五大河流域中的沿湖港口景观类型，并进一步探索这些景观能为半开放湿地提供哪些支持。

2.3 设计研究

HPF项目团队在实验过程中利用传统和新型工具来构思和检验这一月牙形湿地项目。该过程基于景观设计所具有的优异的实验传统，融合了多种媒介、尺度、材料、用途、分析模型和开放式游戏。通过精心设计，该项目将处理沉积物这一过程本身作为人工湿地形成的驱动力；湿地形式摆脱了人类的完全控制，得以承载人类与环境历史，并彰显生态生产力与复杂性。在监管部门、工业部门和休闲娱乐部门贯穿始终的共同努力下，这种方法有助于生成、推进、预测、建模、可视化与检验在不同生态、水文和社会条件下的湿地形态。

为了达到最终目标，HPF项目团队通过参照湿地、物理建模、计算建模、推想图绘制和利益相关者会议来优化设计理念、改进设计方案，使其适用于洛雷恩市的实际情况。



5. 半开放湿地概念设计。这是一个结合了两种现有处理沉积物办法的综合方案。
5. Semi-open wetland concept. It is a hybrid of the two current sediment management options.

2.3.1 参照湿地

考虑到该地区大多数河口湿地既已退化的事实，为了确定在伊利湖沿岸新建湿地的可能性，HPF项目研究了洛雷恩市、阿什塔比拉市和康尼奥特市港口附近存在相似水波状态的几处参照湿地（图7）。这些位于防波堤和码头之间的湿地，是USACE在过去介入干预时无意间留下的产物。水位变化和沿岸漂沙等湖泊水文条件塑造了这些湿地。日复一日，输送到此的沿岸沉积物堆积成土丘，偶发的风暴潮事件在其中开辟出溪流。对于湿地形成过程而言，建立防波措施与保持水文连通性同等重要。USACE对这些参照湿地的初步研究表明，在伊利湖低水位基准线（LWD）^③以上设置一定高程的屏障，足以支持沿湖湿地的建立。人工湿地以半沼泽地为目标形式，由此一来，可以涵盖从新生林地到深水域的各种环境条件，并且会随着时间的推移在空间中产生变化。此外，某些高程区间可能对于高株或矮株的本土挺水植被与沉水植被的生长十分友好，却对芦苇（*Phragmites australis*）等优势种很不理想。

2.3.2 物理建模与形态构建

项目借助物理建模来研究人工湿地的形态，用风暴潮过境后残留沉积物的比例来衡量湿地韧性，

日常冲刷塑造的多样地形来检验湿地的复杂性（图8）。在模型中，某一预设体积的石块和沉积物不断迭代，演变出各种不同的空隙、深度和形状。通过观察这些形态在日常和风暴潮来临时等各种预设条件下的绩效，可以轻松获取韧性、复杂性等较为重要的生态指标，并对其加以对照比较。

HPF项目团队通过建模构建了一种月牙形的槛状结构。这种结构的沿湖沙堤可以抵挡风浪，也可以在风暴潮过境后进行重建，开放的湖岸则加强了与沿岸地区之间的水文连通性。

此外，还研究了哪些空间变化可以优化如下4个变量：减少石材应用、增加沉积物容量，延长湿地周长（影响形态复杂性），并允许可调节性保护措施介入。根据近岸湖底的详细坡度，可以推导出湿地的最佳形状应为椭圆形。沙堤的高度向两侧逐渐降低，确保其中点位置首当其冲地直面并抵挡大浪侵袭，月牙结构的边缘以斜坡慢慢向下延伸至湖底。

除带来环境裨益和引入开放式单元结构的设计理念以外，月牙形结构还具有很强的适应性，即能够根据偏好结果和预期条件来进行缩放、拉伸和旋转。月牙形结构既可以单独设置，也可以串联成组团，用以容纳不同体量的沉积物或承载适配于特定

湿地栖息地类型的理想条件。沙堤高度可以根据特定的水波条件和扰动周期来进行调整。

2.3.3 计算建模和检验

HPF项目团队与Anchor QEA工程公司合作，在湖景区域检验该形态的性能。根据水波情况、近岸测深和泥沙容量，HPF项目团队确定了沙堤和湿地的位置和规模。最终的沙堤设计高度能在平衡湿地营建保护和沉积物留存的同时，应对偶发的干扰性事件。这些偶发事件既可以通过改变沉积物形态创造复杂性，也可以通过中断冗余单一植被（主要是芦苇）生长来提升多样性。为了创建多样的预设形态，HPF项目团队通过改变沉积物相较于水面的高度、沙堤高度和旋转角度创建出几种月牙形结构，形成一版设计方案并对其进行了检验（图9）。借助这种方式，三种湿地类型（即沉水水生植被湿地、矮株挺水植被湿地和高株挺水植被湿地）得以构建，相应的疏浚沉积物容量和构筑物高度也进而得到确认。

Anchor QEA工程公司开发的稳态Delft3D波浪系统模型，可以用来评估干预措施在常规波浪环境和风暴潮波浪环境^④下的效用。近期波浪数据信息^⑤显示，距离洛雷恩港岸线6km的离岸区域的波浪虽然多自东北方而来，但西方的浪高普遍更大。建模结果表明，这些结构如预期般削弱了常规条件下和风暴潮来袭时的波浪（图10）。其中，风暴潮时的影响更为显著——将浪高从2.1~2.4m降低至0.9m以下，达到了和近旁防波堤相似的效用。此外，HPF项目团队还在一系列的推想图中应用了这些模型的计算结果，以进一步解释湿地形态并将其可视化。

2.3.4 推想图绘制

推想图可以帮助理解由环境不确定性（例如湖水水位变化，以及风暴潮发生时间和强度）造成的多样化的潜在结果，而且对于与利益相关方的沟通过程十分必要。相较于已有的封闭式系统和全开放系统，推想图方法对于这样的半开放结构尤其重

③ 数据来源于美国国家海洋和大气管理局潮汐与水流数据库。
④ 常规情况数据来源于2014年高月平均波高（USACE波浪信息研究项目数据）和长期年平均水位（USACE数据）。风暴潮情况数据基于20年重现期的波浪条件（USACE波浪信息研究项目数据）和10年重现期伊利湖水位（NOAA数据）。
⑤ USACE波浪信息研究项目92083号站点数据。

要。因为从计算建模可以得知，预设结构仅在已知或设定环境条件下才具备消浪能力，但整个流域迅速且空前变化的环境条件降低了预测的准确性。HPF项目团队绘制了一系列推想图，来展示可能被利益相关方接受的长期演变结果（图11）。通过这种方式，团队对不同特征场地的可能变化进行可视化，并由此建立起关于项目预期成果的对话。

2.3.5 利益相关方讨论

推想图将未来可能出现的湿地形态概念化，促进不同利益相关方之间围绕预期结果展开讨论，讨论内容包括：哪些湿地形态是可行的？可接受何种程度的形态偏差？以及在USACE50年委托期内以何种时间线规划其预期变化才是可持续的？结合计算建模和参照湿地研究，推想图绘制有助于协调项目以及整个沿湖环境的复杂性、永久性和不确定性。利益相关方的讨论还帮助项目团队在现有封闭式处理设施附近选出了讨论参与方最属意的场地。

2.3.6 基于设计研究的综合性结果

塑造月牙形结构的方案同时满足了近岸湿地对于水文连通性、生态连接度和休闲娱乐连贯性的需求。湿地所采用的防波措施对于栖息地构建至关重要。在生态层面，开放的结构单元提升了湿地与湖泊之间水生栖息地的连通性，为鱼类、鸟类和植物提供了更广阔的生存空间；在水文层面，开放的结构单元模拟消失前的河口，成为了将沉积物和种子带到近岸区域的沉积物处理设施，逐渐流失的沉积物也为释放其他疏浚材料腾退了空间；在休闲娱乐层面，湿地周围受保护的浅水水域将吸引附近钓鱼和划皮划艇的游客前来。最后，在美学层面，简洁而优雅的弧状沙堤更凸显了五大湖流域一望无际的景色。该月牙形结构方案展望了一种新型沉积物管理模式，并通过桥接封闭式和完全开放式方法的技术成果创造一处河口湿地，从而优化湖岸线边界外的近岸环境（图12）。

3 讨论与反思

目前，虽然洛雷恩市某基于204条法案下的湿地项目仍处于可行性研究阶段，但团队正尝试在港口东侧毗邻现有封闭式处理设施处引入部分开放的湿地——其形式和功能都受到月牙形结构的启发。基于上述设计研究过程（包括潜在选址、参照湿地研

地点1：铁路区域
Site 1: railroad site

	与航道的距离 Distance to channel	13km 8 miles
	防波措施 Wave protection	无 None
	沿岸漂沙方向 Littoral direction	自东向西 East to west 自西向东 West to east
	所有权 Ownership	铁路运输公司 Railroad
	公众开放区域 Public access	无 None
	其他 Others	支流 Tributary

地点3：港口区域
Site 3: harbor site

	与航道的距离 Distance to channel	0
	防波措施 Wave protection	东北向与 西北向屏障 Northeast + northwest shadow
	沿岸漂沙方向 Littoral direction	无 None
	所有权 Ownership	公有 Public
	公众开放区域 Public access	垂钓码头 Fishing pier
	其他 Others	无 None

地点2：湖景区域
Site 2: lakeview site

	与航道的距离 Distance to channel	3km 2 miles
	防波措施 Wave protection	东北向屏障 Northeast shadow
	沿岸漂沙方向 Littoral direction	自东向西 East to west
	所有权 Ownership	公有 Public
	公众开放区域 Public access	公园 Park
	其他 Others	侵蚀+水质问题 Erosion+ Water quality

地点4：封闭式处理设施
Site 4: confined disposal facility

	与航道的距离 Distance to channel	3km 2 miles
	防波措施 Wave protection	西向屏障 West shadow
	沿岸漂沙方向 Littoral direction	自东向西 East to west
	所有权 Ownership	公有 / 私有 Public/private
	公众开放区域 Public access	公园 Park
	其他 Others	侵蚀 Erosion

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6. 场地选址。依据后续的研究与发展潜力选出了4处节点场地。
6. Site selection. Four sites were chosen based on the criteria of further research and development.

究、形态优化、物理和计算建模，以及推想图绘制）收集到的信息，设计方案发生了巨大的变化——从由USACE提出的初始状态演变至当前的选址与形态（图13），最终的建造方案也已经大体成型。

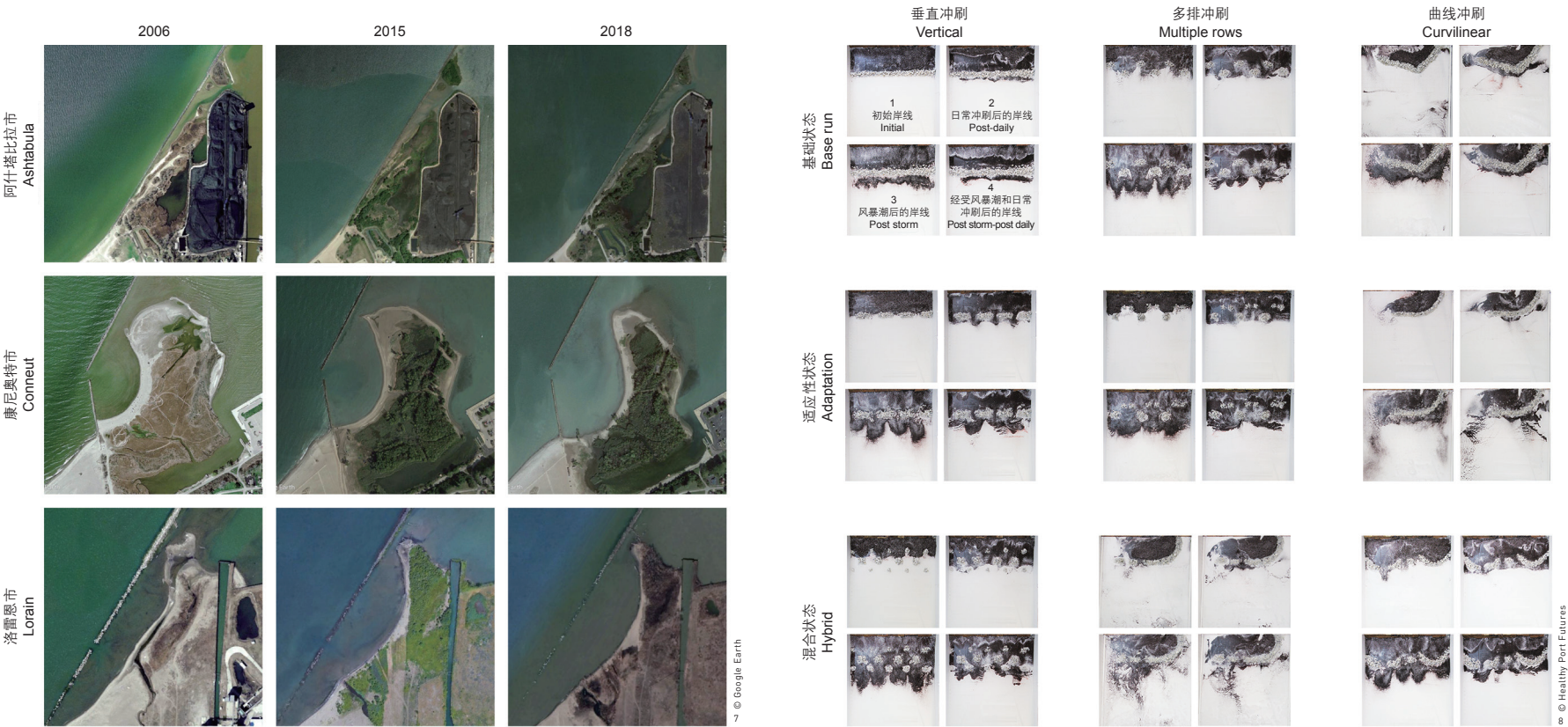
依据利益相关方对于项目预期成果的调整，最终拟建一处保护性更弱但连接性更强的场地。月牙形结构将利用现有构筑物来消解波浪侵袭。根据形态优化研究提出的建议，月牙形结构被置于距湖岸一定距离的湖面之中，以平衡石材损耗与沉积物容积及待建湿地面积。种植着高低起伏的挺水植物的沼泽环绕着堆起的草丘，形成了最终占地3hm²的规划湿地。

湖景公园是一个用于湖滩被动活动与小型船只游湖的沙湾，湿地的开口直接面向该公园。这一设计可以进一步保护沙滩，同时，开放的湿地也能为划皮划艇者、沙滩游客和观鸟者带来额外的审美与娱乐享受。在生态方面，新建湿地将毗邻封闭式处理设施中已建成的湿地，这会鼓励经常光顾邻近栖息地的水禽来到这里。小嘴黑鲈（*Micropterus*

dolomieu）和河鲈（*Perca* spp.）也能进入湿地开放区域，生活在沙堤和沉水水生植被之中。由东向西携带沉积物的沿岸漂沙作用将沙粒冲刷至粘土 / 淤泥厚重的湿地区域。东北向风暴潮的偶发性干扰将进一步促使粘土从湿地经过缓慢的风选过程向近岸转移。

通过平衡保护性与开放性需求，综合考虑区域地貌、波浪条件、土地利用和美学价值，可以在区域范围内布置这些月牙形湿地，并因地制宜地进行改造提升。如此形成的湿地群不仅有望重新恢复沉积物流、健全生态廊道，还可以融入和拓展现有休闲娱乐系统。这一设计理念对于工业河流和工业港口聚集的地区意义深远。事实上，大洛雷恩地区已建成且仍拟建多条可供小型船只、皮划艇和独木舟航行的“蓝色航道”。在俄亥俄州和洛雷恩大都市公园系统相关管理者的共同努力下，一系列沿湖岸新建的湿地将使得“蓝色航道”更加连贯，为各类使用者提供保护并吸引他们前来（图14）。

考虑到场地所具有的不确定性、发生剧变和依



据风险进行调整的可能性，该项目希望重新定义和拓展公众对新建和修复湿地的期望。该项目不再想尽办法防治沉积物流失，而是将这些流失的沉积物视为对近岸区域的养分补充。这项规划并未期望场地自始至终保持同一状态，而是致力于为健康的湿地形成过程创造环境条件，并期望湿地随着时间的推移而变化和提升。通过监测，该项目将为开放式结构单元设计方案的效能提供具体的参考信息，包括其在当地的绩效和在伊利湖区域其他类似地点进行复制的可能性。稳定性和韧性是公共景观应有的、也是公共资助方所需的特性，要想让沿岸和水域区域具备这两项特性，就需要进一步对创新型沿湖与沿河项目进行更为充分的设计研究、实践与监测。

不论是该项目的工作过程还是提出的月牙形结构，都不是放之四海而皆准的，必须结合场地条件进行活用。虽然其他HPF项目的工作过程与本案有着许多相同的组成部分，但由于所处环境、文化、法规和经济背景完全不同，它们的发展路线也各不相同。这些不同的背景为因地制宜地提出设计理

念提供了机会和灵感。正是这种与场所（包括景观本身及其历史经验）的联系，使得HPF项目团队的工作成为一个大体量景观项目的一支，而不是沿湖或沿河工程项目的简单延伸。这一视角对于重新构想和修复湖岸和水域，进而促进生态、经济和人类健康积极发展而言至关重要。湖岸与水域修复不仅是亟待解决的棘手问题，更是广阔历史长河中重要的文化景观^[4]。在进行文化景观设计时，HPF项目将当地沉积物视为促进研究和干预措施生成的积极因素。团队也将其视为景观设计领域最令人兴奋的新兴前沿之一。这项工作既是对土地的科学设计，也是艺术塑造^[5]，由此构想、建立和保护着未来的文化景观。**LAF**

致谢

该项目由五大湖保护基金会支持，是一系列富有建树的合作者们共同努力的成果。他们包括来自OEPA的大卫·埃默曼、来自Anchor QEA工程公司的沃尔特·迪尼科拉和马特·亨德森，以及来自USACE布法罗市分部的阿什利·宾尼恩－祖卡罗、乔什·昂吉尔和格琳·海德斯。

项目信息

项目地点：美国俄亥俄州洛雷恩市
项目面积：3.2hm²
项目委托：俄亥俄州政府
景观设计：“健康的港口未来”项目团队
项目团队：Sean Burkholder、Brian Davis、Theresa Ruswick、Matt Moffitt
项目合作：Zhan Yutong、David Emerman、Walt Dinicola、Matt Henderson、Ashley Binion-Zuccaro、Josh Unghire、Gerlyn Hinds
设计时间：2019年6月至今
建设时间：2022~2024年（预计）
所获奖项：2020年度ASLA分析与规划类荣誉奖
基金支持：五大湖保护基金会

7. 参照湿地。它们为新建湿地的防波措施提供了重要参考。
8. 波浪物理模型。波浪模型显示出在垂直冲刷、多排冲刷和曲线冲刷三种预设的迭代方式下，湿地形态的绩效。
7. Reference wetlands. They provide critical reference information regarding the wave protection necessary for novel wetland establishment.
8. Physical wave modeling. Wave modeling was conducted on iterations of vertical, multiple row, and curvilinear designs, testing their performances under a series of set conditions.

1 Background and Problems

Rivermouths are one of the most vitally important, and perhaps most contested, landscapes of the North American Great Lakes. These liminal lands are critical to the ecological, hydrological, and economic health of the region, but often in conflicting and unaligned ways^[1]. Impacts of rivermouth development and industrialization during the 19th and 20th centuries are now being fully realized. Without the sedimentary processes of a healthy functional rivermouth, valuable habitats languish, leading to the deleterious effects seen across the Great Lakes, including prodigious wetlands loss, shoreline erosion, low water quality, and shrinking undernourished beaches. In particular, the sorting of riverine sediment in the lacustuary zone is one of the most critical and threatened functions of rivermouths. Where the river and lake meet, the variable currents, flows, and waves sort, divert, shape, and transport the sediments. In turn, this material is critical in forming and maintaining coastal habitats, which all local biotic communities rely on. As sediments flow downstream toward flatter lands, they slow down. This sorting process leaves larger sands and cobbles upstream, while smaller sands, silts, and clays move on to interact with the slower flow in the larger lake^① (Fig. 1).

Throughout the basin, many of these rivermouths have been replaced by portlands. Port landscapes seek to restrain the rivermouth into a final form to ensure easy and reliable navigation. In the process, the river- and lake-shore are armored, the once-shifting river channel deepened and straightened, and the rivermouth protected from abrasive waves, impacting important processes, especially those relying on the flush and movement of sediments into the lake. Maintaining the industrial function requires continual management, albeit strenuous, expensive, and repetitive, of this critical mud.

Healthy Port Futures (HPF)^② is an initiative

funded by the Great Lakes Protection Fund, aimed at working with municipalities, state and federal agencies to research innovative sediment design aimed at building coastal resilience of the Great Lakes. As the name suggests, this large project views sediment management within these valuable coastal landscapes as a generator of social and ecological health, not simply something that attempts to avoid harm. Building off the efforts of the Dredge Research Collaborative, HPF continues the innovative work around celebrating and designing with the once-condemned waste product of sediment, believing that there is value in reconsidering the journey of river mud itself as a primary agent in the restoration of ecological assets native to rivermouths.

The focus of this HPF project is a rivermouth port city situated thirty miles (48 km) west of Cleveland in the central basin of Lake Erie (Fig. 2). Lorain, Ohio was once a thriving rivermouth city, however, like many of Great Lake port towns, many of its industries have gone, resulting in vacant but often irretrievably altered river landscapes (Fig. 3). The shoreline reveals the vestiges of the altered coast—past uses have transitioned to current recreational ones. However, significantly absent are Lorain's once abundant coastal wetlands and sandy nearshore.

Ecologically, The Great Lakes coastal wetlands are reliant on the lakes' inherent fluctuating hydrological conditions and large range of spatial and temporal disturbances. The water level variations impact net erosion and net deposition at specific sites by altering the sediment transport. During high water periods, the storm waves erode substrate and, at the same time, place inorganic sediment in previously inaccessible areas. In low water periods, the sediment deposits through littoral drift. This ebb and flow of sediment creates a resilient wetland, able to recalibrate itself after disturbances. The biotic communities are uniquely adapted to these conditions, and

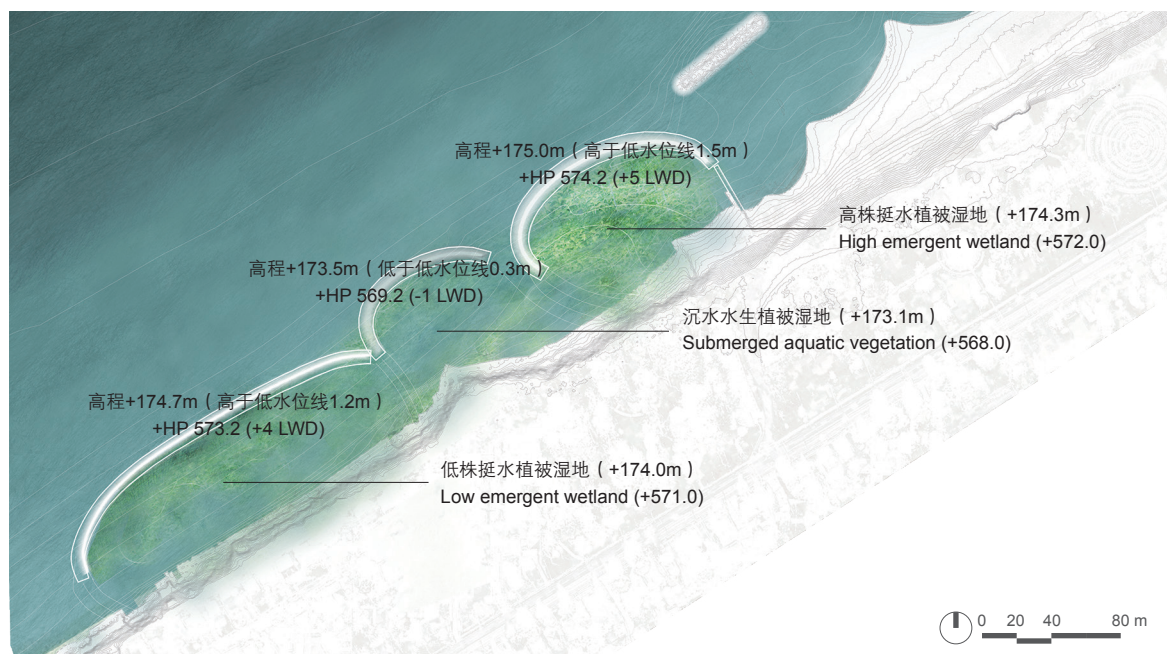
often, the ecological health is reliant on the very unstable and uncertain hydrological environment. This would improve the habitat resilience and complexity by discouraging dominant species, encouraging vegetation succession, and creating variation in vegetation structure and sediment texture^[2]. This diversity in turn benefits the health of different biotic communities, including the benthic invertebrate, fish, and waterfowl^[2].

However, as much as the wetlands are well-adapted to a large range of natural disturbances, anthropological disturbances have led to widespread wetland loss. Historical maps from the early 20th century reveal that the littoral bathymetry along the shore has deepened by approximately two meters, and the soft bottom has been scraped down to hardpan, a compacted clay layer cemented to the lake floor. Gone is the broad shelf of fish habitat and wetlands which dissipated waves and offered protection to the uplands and homes. In its absence, Lorain's nearshore is an environment with intensive wave reflection, where large waves crash onto armored shorelines. Lorain's coastline suffers from long-term sediment loss and displacement, seen clearly in the loss of wetlands, coastline erosion, and subsequent hardening of the nearshore (Fig. 4).

At the scale of the Great Lakes, both sediment placement and wetland creation require innovative, cost-effective, and low-maintenance approaches. Similar to other port cities, in Lorain, sediment has either been confined in the confined disposal facility (CDF)^[3] or unconfined in open deep water. Both practices effectively removed sediment from the nearshore, limiting its vital role in coastal protection, habitat creation, wave attenuation, and beach nourishment. Sediment, long thought to be waste, is now considered a

① This process is clearly defined and well understood by way of what is known as the Hjulstrom curve, which defines the relationships between particle size and velocity, and its corresponding erosional or depositional outcomes.

② For more information about HPF, please visit the official websites of Healthy Port Futures and Great Lakes Protection Fund.



9. 计算模型推导方案。HPF项目团队选定湖景区域并在已知条件下设计方案、构建模型并检验月牙形结构效能。
9. Computational modeling plan. HPF chose "lakeview site" to develop, model, and test crescent shape in known conditions.

commodity—the vital material which can be used to rebuild coastal habitat. While imperfect, these traditional approaches can inform a new innovative practice that draws from the protective characteristics of containment and the cost-efficiency of non-containment. This pilot project could expand upon past knowledge and experiment with novel techniques that demonstrate broad application.

2 Design Process

Lorain's effort of beneficial wetland reuse and creation is spearheaded by both the Ohio Environmental Protection Agency (OEPA) and the Buffalo District of the United States Army Corps of Engineers (USACE), and as such, needs to address the objectives of both coordinating agencies. Simply put, the project must address the navigation concerns of USACE and the ecological concerns of OEPA. The HPF team joined in during the feasibility phase to help in siting, communication with public stakeholders, and concept development to bridge the objectives and

values of multiple stakeholders.

Involved in overseeing the dredging, transportation, and placement of the sediment, USACE have specific requirements on the construction of the project: The constructed wetland habitat should have a certain level of permanence, existing in its form for at least 50 years, thus requiring an environment that supports its establishment and longevity. Additionally, the wetland can sustain itself only with minimal maintenance.

OEPA has similar but more ecologically motivated objectives: The state views the series of beneficial reuse projects as an opportunity to explore an innovative regional approach to wetland re-establishment along the Ohio coastline, and the restoration of their ecological functions. The re-established wetlands would be of high quality, allowing for a diversity of native flora and fauna to thrive.

Municipality and community stakeholders are concerned with the integration of the wetlands into the social and economic health of the city. The wetlands could attract and boost the

recreational activities already seen along the Ohio coast. Anglers, kayakers, surfers, and birders would benefit from the introduced habitats. Additionally, coastal landowners are worried about losing their shoreline, as addressing erosion has become increasingly costly. Offshore structures and wetlands could facilitate wave attenuation and protection in localized areas, sited in a way that could protect important onshore municipal infrastructure. Lastly, the wetlands could provide additional sediment to the nearshore, thus mitigating some of the erosive effects beyond its localized form.

Working with regulators, contractors, and the community stakeholders in a collaborative way is fundamentally important to the development of the project. Early on, an agreed-upon vision of a network of coastal wetlands helped guide decisions on how the regulations should be interpreted. This involved working with regulators and ecologists at OEPA and USACE in determining how to realize this vision through sediment placement while meeting related regulation requirements and community needs. Through this collaborative process, regulations are no longer roadblocks, but serve as a method to achieving a collective vision.

2.1 Design Concept

During this project, HPF focused on restoring the rivermouth wetlands' foundational function of sediment processing. HPF conceived of an approach in which sediment sorting, movement, and use could be facilitated by a novel constructed wetland. This process would hybridize the mechanical forces utilized by the USACE with the natural forces of waves and currents. The sediment will be first placed mechanically, then dispersed, trapped, and sorted by the waves and currents within the wetland. In this way, the riverine sediment would be re-integrated into the nearshore system, available to be used to build rivermouth wetlands, nourish the nearshore, and build the beaches, helping partially mitigate

many of the problems caused by the industrialized rivermouth.

To create a wetland that allows for hydrological and geological connectivity, HPF conceived of a semi-open wetland design (Fig. 5). This hybridized approach will balance the needs for protection from waves and connectivity to the lake, which oftentimes require contradictory environmental conditions for healthy coastal wetlands: The lakeside structure will provide wave protection necessary for wetland establishment while still allowing for occasional stochastic disturbance events. This system intentionally employs waves and currents in creating ecological complexity and maintaining diversity. The shoreside opening will encourage critical hydrological and ecological connectivity to the nearshore and allow for both sediment drift into the cell and sediment loss into the environment, thus promote the redistribution of critical

sediment into the nearshore. Instead of a fortified, permanent, and isolated wetland, the semi-open wetland is permeable, dynamic, and connected—these characteristics are inextricably linked.

Both temporally and spatially, placing sediment in a semi-open system nearshore is significantly and inherently different from the now highly discouraged practice of open deep-water placement. The semi-open wetland placed in the nearshore emulates the rivermouth. Daily waves slowly winnow out smaller suspended sediment, while occasional storm events lead to more substantial pulses, as larger sediments leave the cell or are re-arranged within it. In contrast, the open-water placement is timed by the dredging schedule, which is different from the natural process. Furthermore, the placement in the nearshore promotes the nourishment of sediment-starved littoral zone, which is the normal destination of riverine sediment in a

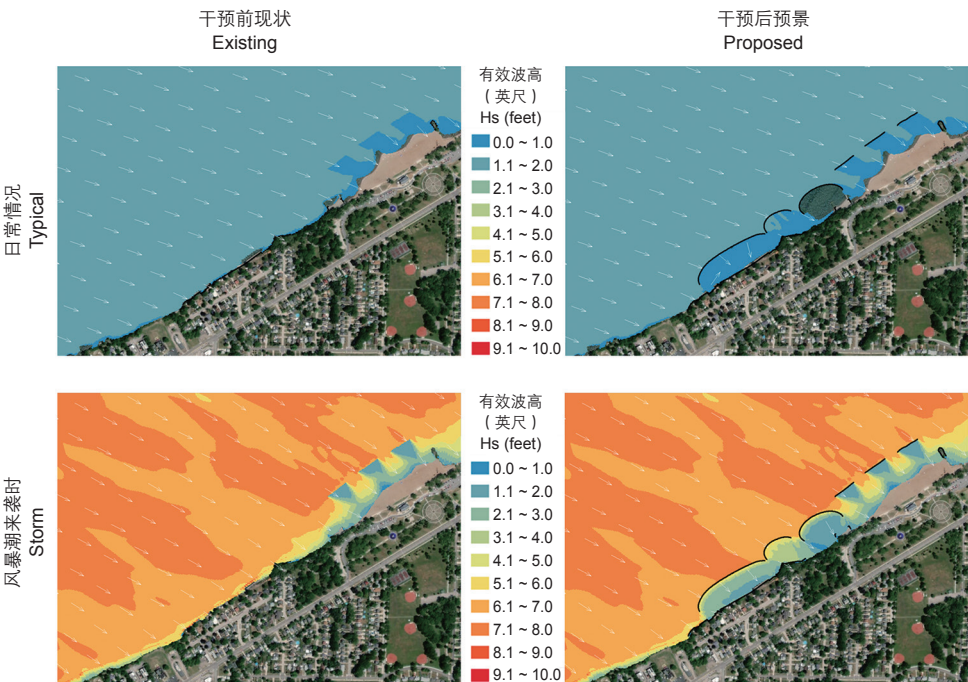
natural rivermouth system. Sediment placed in the open lake has no such additional ecological benefits, but rather disturbs important benthic habitats with foreign clays and silts.

2.2 Site Selection

Based on stakeholders’ objectives and HPF’s background research, potential sites along Lorain’s coastline were selected for further detailed study and exploration (Fig. 6). These sites were chosen for specific characteristics of importance to stakeholders, including proximity to navigation channels, existing wave protection, public ownership, and presence of recreational and/or ecological infrastructure. Despite the similarities, these selected sites represented a wide range of different coast-port landscape typologies. The first site, located several miles west of Lorain’s navigation channel, is a long stretch of coast adjacent to railroad revetment which offered the opportunity to experiment more freely. The other three sites are all located within proximity to the channel, and thus benefit from the protection of the harbor wave breakers, short transport distances, and public access. Through a more detailed study, HPF will use these diverse sites to represent the types of coastal-port landscapes found across the Great Lakes, and to explore the potential for these landscapes to support the semi-open wetlands.

2.3 Design Research

HPF utilized both conventional and alternative tools in an experimental process to develop and test the “Crescent” project. This process builds on the best experimental traditions



情形 Case	水面高程 (参照国际大型湖泊基准面1985) Elevation (IGLD85)	有效波高 Wave height (Hs)	波浪周期 (秒) Wave period (sec)	波浪方向 Wave direction
日常情况 Typical condition	174.1m / 571.3 ft	1.0m / 3.3 ft	3	西 West
风暴潮来袭时 Storm condition	175.2m / 574.7 ft	4.1m / 13.6 ft	7.1	西 West

© Anchor QEA
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10. 计算建模检验结果。建模结果对比了在日常情况下和风暴潮来临时，采取干预措施和不施加干预下的湖岸带情况。表格中显示了在无干涉和介入干涉预设场景中使用的波浪参数。
10. Computational modeling results. The modeling results show proposed interventions in contrast to existing conditions under typical wave and storm wave events. The table indicates wave parameters used in the model for both existing and proposed scenarios.

of landscape architecture, mixing varied media, scales, materials, values, modes of analysis, and open-ended play. It was carefully and intentionally created to position sediment itself as an active driver of the designed wetland form that eluded complete control, carried human and environmental history, and enabled ecological productivity and complexity. This approach, when coupled with early and consistent collaboration across sectors (regulatory, industry, and recreational), helped generate, facilitate, speculate, model, visualize, and test wetland forms under a range of ecological, hydrological, and social conditions.

To this end, HPF utilized reference wetland sites, physical modeling, computational modeling, speculative drawings, and stakeholder meetings to advance this concept, refine the design, and calibrate it to Lorain’s conditions.

2.3.1 Reference Wetlands

To determine whether new wetlands could be established along Lake Erie’s coast, HPF researched several reference wetlands remaining near the harbors of Lorain, Ashtabula, and Conneaut (Fig. 7) that are of similar wave conditions, while most of the rivermouth wetlands have been lost. These wetlands, wedged between the breakwaters and jetties, are the unintentional byproduct of past USACE interventions. Responsive to the lake’s hydrological conditions, these wetlands are formed by the changing water levels and drift of littoral sediment. The daily longshore sediment transport forms the mounds and hummocks

while the occasional stochastic storm events shape the rills and creeks. As important to wetland formation as maintained hydrological connection is calibrated wave protection. According to an initial USACE study on these referenced wetlands, particular barrier elevations above Low Water Datum (LWD)^③ on Lake Erie would be sufficient to support the establishment of coastal wetlands. A hemi-marsh was selected as the goal for the created wetlands, as they demonstrate a wide range of conditions from emergent woodlands to deep water and tend to fluctuate spatially over time. Additionally, certain elevations would encourage native low and high emergent vegetation, as well as submerged vegetation to thrive, while discouraging the growth of dominant species like *Phragmites australis*.

2.3.2 Physical Modeling and Form Development

In this project, through physical modeling, the forms of constructed wetlands were explored: Resilience was determined by the percentage of sediment retained after storm events while complexity was measured by the amount of topographic variation created by daily events (Fig. 8). By being iterated on a specific set volume of stone and sediment in the model, these forms had varied spacing, depth, and shape. By observing the forms’ performance under a prescribed series of daily and storm conditions, important metrics, such as resiliency, and complexity, were easily compared.

Through the modeling process, HPF developed a crescent sill structure. The structure’s lakeside crest provided wave protection and

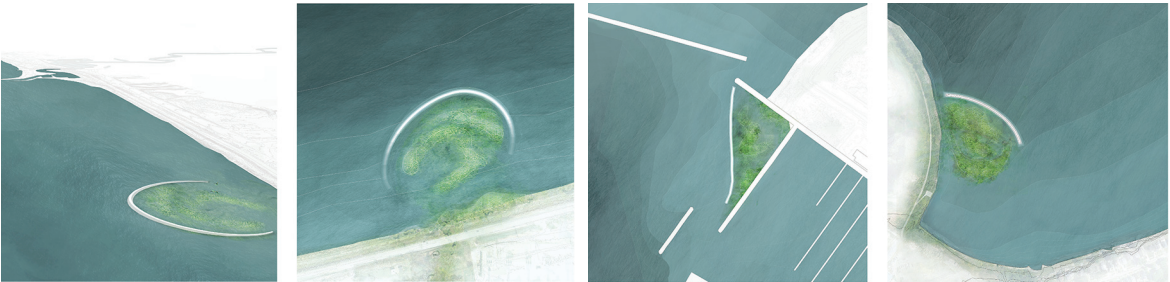
re-establishment after storm events, while the shoreside opening encouraged hydrological connectivity to the nearshore.

Additional studies were then conducted to explored spatial variations designed for the optimization of 4 variables: minimizing volume of stone utilized, maximizing volume of sediment placed, maximizing the perimeter length of each type of wetland (affecting form complexity), and allowing for variable protection. Based on the particular slope of the nearshore lake floor, the optimal shape is an oval. The sill adopts a declining height, so that its crest (the midpoint) is the highest to resist against the greatest wave impact, while the crescent edges slope gently towards the lake floor.

Beyond its environmental benefits and its open-cell concept, the Crescent is also highly adaptable to be scaled, stretched, and rotated depending on preferred outcomes and anticipated conditions—It can be used either individually or in tandem to hold different sediment volumes or achieve desired conditions suitable for specific wetland habitat types. The sill height can be tuned to specific wave environment as well as disturbance period.

2.3.3 Computational Modeling and Calibration

HPF collaborated with the engineering firm Anchor QEA to test the form’s performance at the “lakeview site.” HPF sited and scaled the sill and wetland form based on the wave conditions, nearshore bathymetry, and sediment capacity. The desired height seeks to balance protection for wetland establishment and



③ The data was sourced from National Oceanic and Atmospheric Administration (NOAA) Tides and Currents.

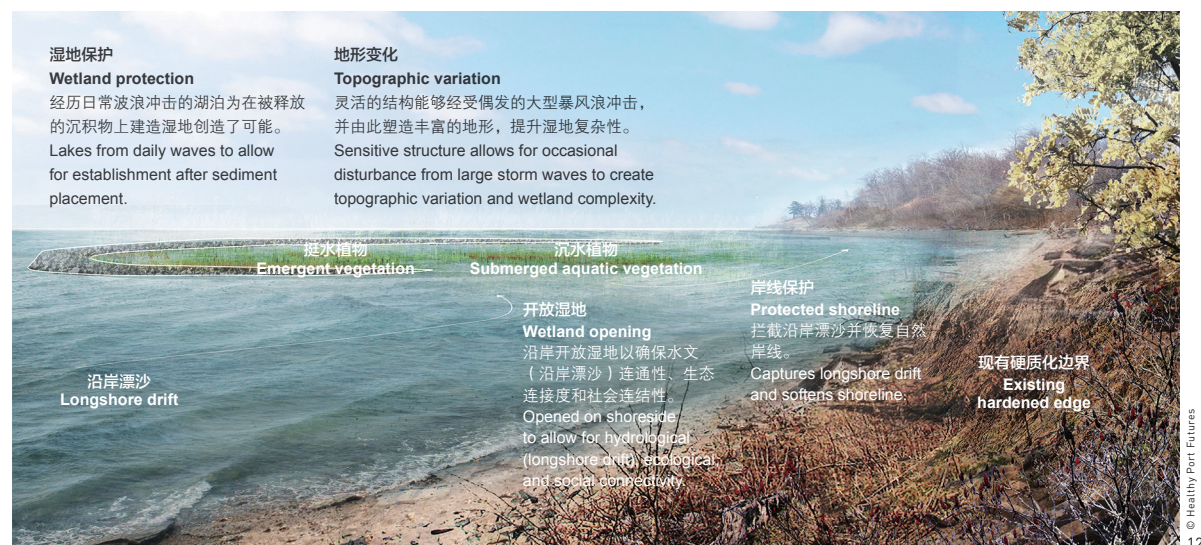
11. 推想图纸。这些图纸通过展示几种预设湿地形态的不稳定变化，促进了关于湿地演化和持久性的讨论。
11. Speculative drawings. By demonstrating the fluidity of potential wetland forms, these drawings helped facilitate discussion around wetland change and permanence.

sediment retention while allowing for occasional disturbance events. These occasional disturbance events are intended both to create complexity through deformation of placed sediment, and to encourage diversity through disruption of unwanted monoculture vegetation growth (primarily *Phragmites australis*). To provide a range of potential forms, HPF tested a design that utilized several crescent forms by altering sediment height in relation to water elevation, sill height, and rotation (Fig. 9). In this way, three different wetland types—submerged aquatic, low emergent, and high emergent vegetation—were targeted and corresponding dredged sediment fill and structure heights were then designed.

Anchor QEA developed a steady-state Delft-3D-WAVE model to evaluate the impact of the interventions on both the typical wave and storm wave conditions^④. Based on the closest wave data information^⑤, located approximately four miles offshore of Lorain Harbor, the largest percentage of waves were from the Northeast, while the largest percentage of larger wave heights were from the Westerly directions. The modeling results showed that, as expected, the structures dissipated both the typical and storm waves (Fig. 10), but had a clearer impact on the storm waves, diminishing them from 7 ~ 8 feet (2.1 ~ 2.4 m) to less than 3 feet (0.9 m), similar to the adjacent breakwaters. Additionally, in a series of speculative drawings, HPF used these modeling results to further interpret and visualize the potential range of wetland forms.

2.3.4 Speculative Drawing

Speculation is needed to understand and communicate to stakeholders, the range of potential outcome that result from environmental uncertainties, such as the variation of lake levels, and the time and intensity of storm events. This is especially necessary for this semi-containment system than previously established containment and



12. 从湖岸看到的湿地景象。湿地的开放一侧面向湖岸，既创造了视觉焦点，又提高了休闲场地的可达性。

12. View from the shore. The open-side of the wetland will face the shore, both creating visual attraction and promoting recreational accessibility.

non-containment systems, as computation modeling can demonstrate the structures' ability to attenuate waves only under a set of known and prescribed conditions, but the rapidly changing and unprecedented conditions seen across the basin reduce the prediction accuracy. HPF developed a set of speculative drawings to define potential and stakeholder-accepted range of outcome over a long period (Fig. 11). In this way, the team was able to facilitate conversations about expectations by visualizing the possible variations with the features of each site.

2.3.5 Stakeholder Discussions

Conceptualizing the range of potential future formations, the speculative drawings aided in facilitating discussions around expectations and assumptions among different stakeholders. These discussions explored topics such as: What is the allowable range of wetland morphologies, the acceptable degree of morphology deviation, and a sustainable timeline of potential changes with respect to the USACE 50-year mandate?

- ④ Data of typical conditions were sourced from the high monthly mean wave height in 2014 (USACE Wave Information Studies data) and the long-term annual average water level (USACE data). Data of storm conditions were based from the 20-year return period wave condition (USACE Wave Information Studies data) and the 10-year return Lake Erie level (NOAA data).
- ⑤ Retrieved from USACE Wave Information Studies (WIS) Station 92083.

When paired with computational modeling and study of reference wetlands, the speculative drawings helped mediate complexity, permanency and uncertainty of the project, and the coastal environment in general. These discussions also assisted in the selection of the participant-preferred site located adjacent to the existing CDF.

2.3.6 Synthetic Outcome Based on Design Research

The Crescent approach navigates the need for hydrological, ecological, and recreational connectivity of wetland nearshore with the wave protection critical for habitat establishment. Ecologically, the open cell allows for increased aquatic habitat connectivity between the wetland and lake, providing more living space for fish, birds, and plants; Hydrologically, the open cell imitates the lost rivermouth acting as a sediment processor, which allows for sediment and seeds to be winnowed out into the nearshore, while the gradual loss of sediment allows for

the placement of additional dredged material; Recreationally, the shallow, protected waters around the wetland will attract nearby anglers and kayakers; Lastly, aesthetically, the simplicity and elegance of the curved sill seeks to highlight, and not detract from, the vast expanse of the Great Lakes. The Crescent envisions a new mode of sediment management, and by bridging the knowledge of containment and non-containment methods forms a rivermouth wetland that seeks to heal the nearshore environment beyond its limited boundaries (Fig. 12).

3 Discussion and Review

Currently, the 204 project in Lorain, while still in the feasibility stage, is calling for a partially open wetland site—inspired formally and functionally by the Crescent—on the east side of the harbor, adjacent to the existing CDF. Based on the information gleaned from the design-research processes mentioned above, including potential site location selection, reference wetland study, shape optimization, physical and computational modeling, and

speculative drawing, the design has changed dramatically from its initial state to the current location and figuration, as proposed by the USACE (Fig. 13), hinting what will ultimately be constructed.

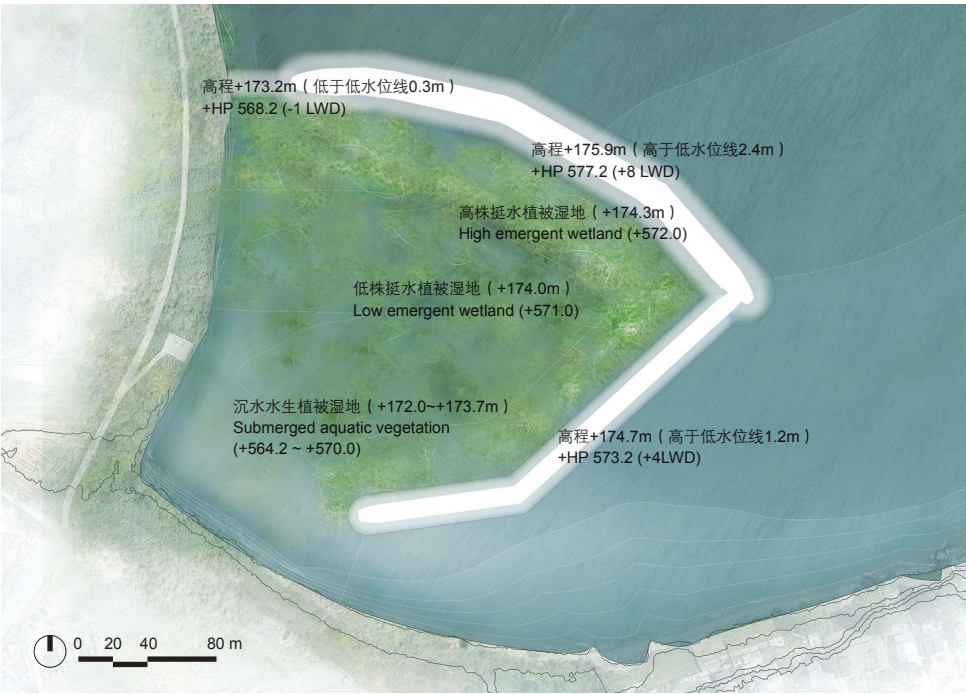
The change of stakeholders’ expectations led to a less protected, but more connected, preferred site. The Crescent will utilize the wave protection by the existing structure. As recommended by the shape optimization studies, the Crescent structure is placed at a specific distance offshore balancing stone cost with sediment capacity and potential wetland acreage. The planned wetland will be 8 acres, composed of an elevated sedge mound surrounded by high and low emergent marshes.

The open side of the wetland directly faces Lakeview Park, a sandy cove utilized for passive beach activities and as a small boat launch. The design could further protect the beach and create additional aesthetic and recreational value of open wetlands for kayakers, beachgoers, and birdwatchers. Ecologically, the newly created wetland will be adjacent to the already established wetland in the CDF, which will encourage the use of the site by waterfowl

frequenting the neighboring habitat. Smallmouth bass (*Micropterus dolomieu*) and perch (*Perca* spp.) will be able to access and utilize the sill as well as the submergent aquatic vegetation established in the wetland’s open area. The littoral drift, which transports material from east to west, can deliver a much-needed flush of sand to the clay/silt-heavy wetland. Occasional disturbances from northeastern storms would further allow for a slow winnowing of clay out of the wetland into the nearshore.

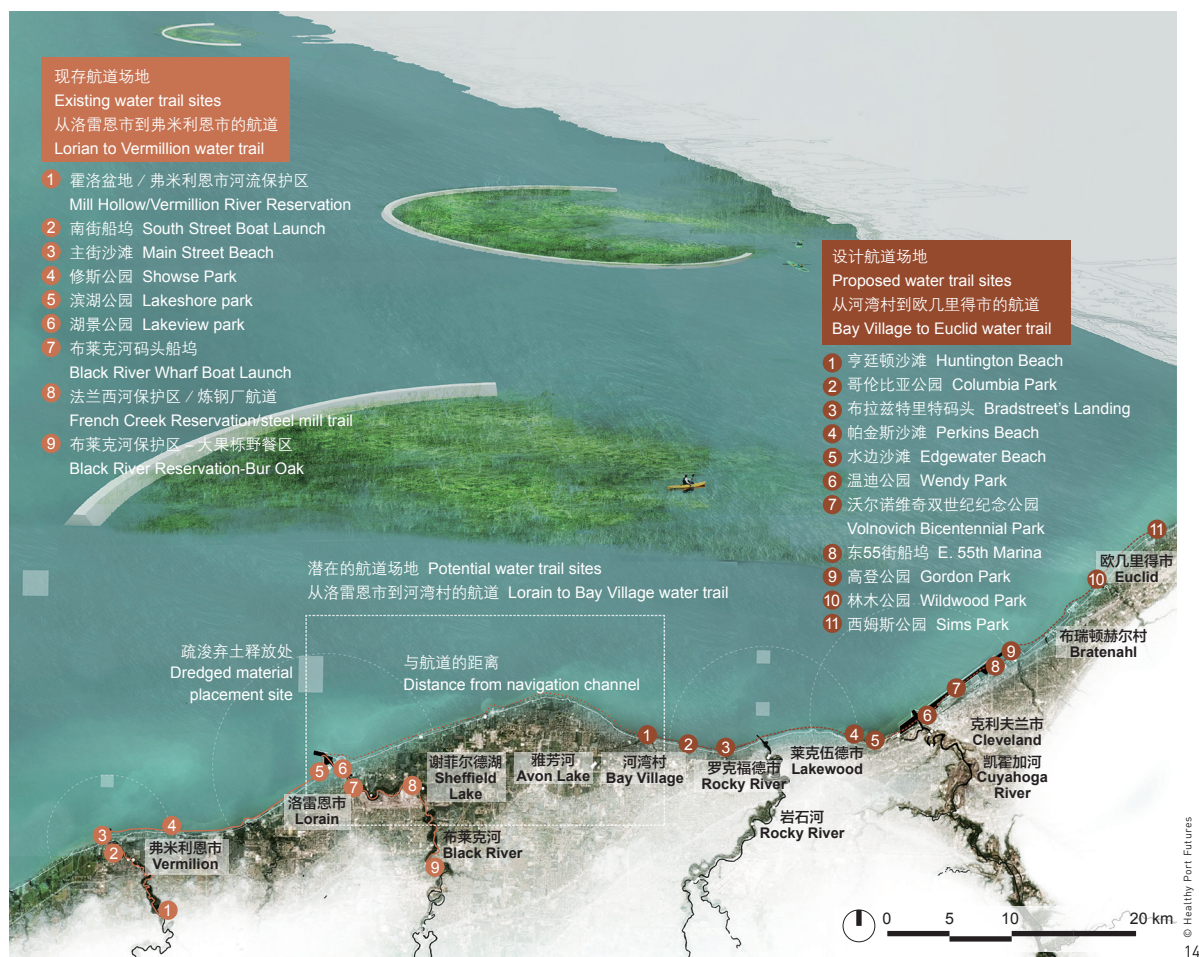
Balancing the need for protection and openness and combining regional geomorphology, wave conditions, land use, and aesthetic values, these crescent wetlands might be regionally deployed while being optimized for local conditions. The replications of the wetland have the potential to not just reconnect the sediment flow and strengthen ecological corridors, but also join in and expand upon existing recreational networks. In regions with numerous industrial rivers and ports, this idea could be far-reaching. Indeed, within the greater Lorain region, there are several existing and proposed “blue trails”—regional waterways used by small boaters, kayakers, and canoers. Driven largely by local efforts, including those of Ohio and Lorain Metroparks, the blue trails will be gradually connected by a series of created wetlands along the coast, offering protection and more attraction to various users (Fig. 14).

By acknowledging uncertainty, potential for dramatic changes, and calibrating for risk, this project hopes to redefine and broaden public expectations around wetland creation and restoration. Instead of fortifying against sediment loss, this project facilitates the loss as



13. USACE的预期设计方案。应用于湖港东部的当前设计方案，受到HPF项目团队半开放式月牙形设计理念的影响。

13. Potential USACE design. The current iteration of this design, calibrated to be placed east of the harbor, is influenced by HPF’s semi-open Crescent concept.



14. 区域性航道。一条待开发的航道将连接现有洛雷恩市-弗里利恩市航道与待建的从河湾村到欧几里得市的航道，并串联起整个区域内的休闲场地。

14. Regional water trail. A potential water trail could connect the existing Lorain-Vermillion Water Trail with the Proposed Bay Village-Euclid Water Trail, creating recreational connectivity throughout the region.

gain to the nearshore. Rather than planning for permanence, this project focuses on creating the conditions for healthy wetland formation and expects the wetland to deform and reform over time. Through monitoring, the project will provide specific reference information on the efficacy of the open-cell design, both in its local performance and its transferability to similar sites in Lake Erie. More robust design research, implementation, and monitoring of innovative coastal and riverine projects are needed for reimagining our coasts and waters with both the assurance and resilience that a public landscape deserves and that public funding demands.

The working process for the project as well as the form of the Crescent must be understood

as contextual but not universally applicable. The working process for other HPF projects, while containing many of the same components, have evolved along very different lines due to the fundamentally different environmental, cultural, regulatory, and economic contexts they are situated within. These contexts provide opportunity and inspiration for the development of ideas that are specifically tuned to a place. It is the connection to place—to the landscape and its experience—that makes the work HPF is doing part of a larger landscape project, not an extension of coastal or riverine engineering. Such perspectives are essential to reimagine and restore coastlands and waters as engines of ecological, economic, and human health.

The restoration of coastlands and waters is not merely problems to solve; it is the great cultural landscape project of our time^[4]. The HPF project understands the sediment of these places as the active agent of study and intervention when communicating with these cultural landscapes. The team believes that this is one of the most exciting new frontiers for the field of landscape architecture, which re-established itself between the science and art of the land^[5] to imagine, develop, and protect cultural landscapes of the future. **LAF**

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PROJECT INFORMATION

LOCATION: Lorain, Ohio, USA

AREA (SIZE): 8 acres

CLIENT: State of Ohio

LANDSCAPE DESIGN: Healthy Port Futures

PROJECT TEAM: Sean Burkholder, Brian Davis, Theresa Ruswick, Matt Moffitt

COLLABORATORS: Zhan Yutong, David Emerman, Walt Dinicola, Matt Henderson, Ashley Binion-Zuccaro, Josh Unghire, Gerlyn Hinds

DESIGN PERIOD: June 2019 to present

CONSTRUCTION PERIOD: 2022 ~ 2024 (estimated)

AWARD: 2020 ASLA Analysis and Planning Honor Award

FUND: Great Lakes Protection Fund

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