U.S. Fish & Wildlife Service

Potential Wetland Restoration Sites for Connecticut: Results of a Preliminary Survey

May 2013

Cover Photos: Lynde Point Marsh, a restored tidal wetland in Old Saybrook: top = post-restoration view, while other photos show restoration activities: spraying and mowing of common reed stands and removal of dredged material and excavation of ponds. (CTDEEP photos)

U.S. Fish and Wildlife Service

Potential Wetland Restoration Sites for Connecticut: Results of a Preliminary Statewide Survey

Ralph W. Tiner[1], Kevin McGuckin[2], and Jason Herman[2]

[1]U.S. Fish and Wildlife Service
300 Westgate Center Drive
Hadley, MA 01035

2Conservation Management Institute
Virginia Tech
1900 Kraft Drive, Suite 250
Blacksburg, VA 24061

May 2013

This report should be cited as: Tiner, R.W., K. McGuckin, and J. Herman. 2013.
Potential Wetland Restoration Sites for Connecticut: Results of a Preliminary Statewide
Survey. U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA.
24 pp. plus appendix.

Table of Contents

This page is intentionally blank.

Introduction

In 2010, the Connecticut Department of Energy and Environmental Protection (CTDEEP) contacted the U.S. Fish and Wildlife Service (FWS) about their interest in updating the 1980s wetland inventory for Connecticut. Besides updating and enhancing the wetlands inventory, CTDEEP wanted the FWS to apply recently developed procedures for identifying potential wetland restoration sites. CTDEEP provided funds to the FWS to update and enhance the wetlands inventory and produce a statewide inventory of potential wetland restoration sites. The purpose of this report is to summarize the findings of this analysis.

Types of Wetland Restoration Sites

"Wetland restoration" is a widely used term that covers both re-establishment and rehabilitation of wetlands. Re-establishment involves the process of reviving a former wetland to produce a gain in wetland area (acreage) as well as function. Re-establishment is called Type 1 restoration in this paper. Rehabilitation involves rejuvenating an impaired wetland (e.g., a partly drained or impounded wetland) bringing it back to a more natural condition. Rehabilitation results in an increase in wetland functions that ideally creates conditions more like that of natural wetlands. It does not result in an increase of wetland acreage. Rehabilitation is called Type 2 restoration in this paper. Two other situations are sometimes confused with wetland restoration: wetland creation (or establishment) and wetland enhancement. Creating a wetland from dryland by excavating a depression or impounding a stream is not considered restoration. Neither is altering a natural wetland to change its functions, e.g., diking a wet meadow to convert it to a marsh for the benefit of waterfowl. This type of activity is considered wetland enhancement and increases one or more wetland functions at the expense of others.

Former wetlands that have potential for re-establishment (Type 1 sites) are mostly effectively drained lands that are often used today for agriculture (e.g., cropland or pasture), while others are now open water bodies or filled land that is relatively undeveloped. For the former sites, restoring hydrology through plugging ditches or breaking tile drains is the main technique used to bring these lands back to a functioning wetland, yet dikes and water-control structures have been used in some situations. The first of the latter sites are former wetlands that are now dammed or diked. Restoring them back to wetlands would involve dam or dike removal or breeching the dike in one or more places. Filled former wetlands would require removal of fill, re-grading, and possible re-creation of drainage patterns (e.g., creeks in tidal marshes).

Existing wetlands that have been altered by ditching, excavation, impoundment, or by road or railroad crossings are candidates for rehabilitation (Type 2 sites). A variety of restorative measures may be applied depending on the nature of the alteration, e.g., ditch-plugging, adding fill to restore elevations, dike breeching, or removal of tidal flow restrictions. Where invasive species are to be controlled, application of herbicides and other treatments (e.g., periodic mowing) may be required.

Methods

Data Sources

Analysis of several sources of geospatial information through geographic information system (GIS) technology was performed to build a statewide database of potential wetland restoration sites. Three primary sources were used for this analysis:

- Existing soils data (U.S.D.A. Natural Resources Conservation Service; http://soildatamart.nrcs.usda.gov/Survey.aspx?State=CT),
- the updated and enhanced wetlands inventory (the NWI+ database; Tiner 2013, Tiner et al. 2013), and
- 2010 four-band infrared digital aerial imagery (U.S. Geological Survey, National Aerial Imagery Program; http://www.ctecoapp3.uconn.edu/ArcGIS/Services/images/Ortho_2010_4Band_NAIP/ImageServer).

A fourth data source – 1890s topographic maps – from the U.S. Geological Survey (http://geonames.usgs.gov/pls/topomaps/) was used to help identify the original condition of some areas.

Geographic information system technology (GIS) was used to combine digital imagery with geospatial data bases on soils and wetlands. ESRI's ArcGIS 10.0 was the GIS platform used for this project.

Identification of Type 1 Sites (Former Wetlands)

The U.S.D.A. soil data provide the foundation for identifying Type 1 sites (former wetlands). Soil map units dominated by hydric soils are viewed as historic or contemporary wetlands (depending on current conditions), recognizing data limitations (see "General Scope and Limitations of the Inventory"). Hydric soil map units that were not mapped as a wetland or P-wet areas (undeveloped, "naturally" vegetated hydric soils not mapped as a 2010 wetland) during the current update and that upon examination of the 2010 aerial imagery were cropland, pasture, barren land, or other idle land were viewed as having some potential for restoration. Most of these areas were expected to be effectively drained former wetlands (Figure 1). Dredged material disposal sites constructed in tidal marshes were a less common Type 1 site. They were interpreted from the aerial imagery and verified as marsh via the 1890s topographic maps. All "dryland" Type 1 sites were delineated and entered into the expanded database (NWI+ database). A geospatial data layer was created from a hydric soil data layer by viewing that layer and the 2010 wetlands data on the 2010 digital imagery and delineating those areas that were in a land use that may be suitable for wetland restoration. Hydric soil areas that were not mapped as wetlands by the current survey and on the 2010 imagery appeared as an open land use (agricultural or barren land) were classified as potential Type 1 wetland restoration sites.

The “deepwater habitat” Type 1 sites were identified by analyzing the soil characteristics of all deepwater habitats. If the soil survey mapped the area as “water” it was not considered a former wetland. If however, the deepwater habitat or a portion of that habitat occurred within a hydric soil map unit, it was classified as a Type 1 site. These polygons were delineated, classified as Type 1 sites, and entered into the NWI+ database.

Figure 1. Type 1 site – a former palustrine forested wetland, now cropland on hydric soil (code 9 = Scitico, Shaker, and Maybid soils; Bloomfield). (Source: USDA web soil survey)

Another set of potential Type 1 sites were identified during the preparation of this report. Several dump or fill sites located in former tidal wetlands were identified on the aerial imagery. They were not situated on a hydric soil map unit but were on “Udorthents” – a soil mapping unit that includes filled land (e.g., dredge disposal sites) and land cut for leveling. The 1890s topographic maps were consulted to verify their prior status as tidal marshes. Several prominent sites were included in the Appendix of this report.

Identification of Type 2 Sites (Existing Impaired Wetlands)

Since Type 2 sites are existing wetlands with some type of impairment, most could be identified by consulting the mapped wetland type in the enhanced wetland database and searching for “special modifiers:” partly drained/ditched (“d” modifier), diked/impounded (“h” modifier), excavated (“x” modifier), and farmed (“f” modifier). While all such wetlands are impacted, some of these wetlands may be created by these actions (e.g., excavated depression or impounded stream). To sort out possible created wetlands from altered natural wetlands, soil survey data was consulted to identify the likely presence of hydric soil. Our approach was conservative: if more than 50 percent of the wetland fell within a hydric soil map unit, it was considered a natural wetland and classified as a potential wetland restoration site. The other sites may have been created wetland and were not included as Type 2 sites. An exception was made for some ditched tidal marshes that did not match up with a hydric soil. These wetlands were on the U.S. Geological Survey topographic maps and are not likely to be created wetlands. All ditched estuarine wetlands were identified as potential restoration sites. An examination of aerial imagery and contemporary U.S. Geological Survey topographic maps revealed a small number of salt marsh polygons in the enhanced wetland inventory that lacked a ditched/partly drained modifier despite the presence of ditches. The "d" modifier was added to these wetlands and the database updated accordingly.

The enhanced wetlands inventory involved applying hydrogeomorphic and other descriptors to improve wetland characterization (Tiner et al. 2013). This work included adding new descriptors for identifying Type 2 sites that were tidally restricted wetlands. Along the coast, tidal flow is limited by roads ("td" modifier), railroad embankments ("tr" modifier), or by other structures, usually built-up land ("to" modifier) (Figure 2; Tiner 2011).

Figure 2. Estuarine wetland (salt marsh) that is tidally restricted by roads and former rail causeway (Milford). The light brown areas along the marsh edge appear to be mowed common reed (*Phragmites australis*) stands.

Target Mapping Unit

The target minimum mapping unit for identifying a potential restoration site was set at 0.5 acre. During the interpretation some sites smaller than this were mapped where the feature was obvious and readily delineated.

Database Construction

The wetland restoration database was created in ESRI's ArcMap 10.0. Two restoration layers were created: one for Type 1 sites and the other for Type 2 sites. The distribution and characteristics of these areas are displayed via an ESRI-based online mapping tool – NWI+ Web Mapper – posted on the Association of State Wetland Managers webpage "Wetlands One-Stop" (http://aswm.org/wetland-science/wetlands-one-stop-mapping).

General Scope and Limitations of the Inventory

The quality of the data sources used for any inventory is a major limitation of any mapping effort. The data sources used for this inventory of potential wetland restoration sites are no exception: soil survey data and wetland inventory data interpreted from aerial imagery. Also it is not a simple matter to separate effectively drained hydric soils from partly drained soils through image analysis since the images capture conditions at a single moment in time.

Type 1 Sites

Hydric soil map units are generalized areas derived from a combination of aerial photointerpretation and on-the-ground soil mapping. All soil map units may contain soils of a different type ("inclusions"; USDA 2008). Consequently hydric soil mapping units may contain nonhydric soil areas as inclusions. Table 1 lists the hydric soil mapping units used to help identify former wetlands for Connecticut and shows the percent of the unit that is expected to be hydric. While most of these units are reported to have over 80 percent hydric soil, the floodplain soils (Fluvaquents and Udifluvents) may contain 39 percent nonhydric soils. Thirteen of the soil map units on the list contain soils classified as Aeric subgroups (e.g., Aeric Endoaquepts). These soils are listed as poorly drained soils, but their official description recognizes that they include both poorly drained and somewhat poorly drained members. Nine soil series on the list fall into this category: Brayton, Fredon, Leicester, Moosilauke, Raynham, Raypol, Ridgebury, Shaker, and Walpole. Type 1 sites or portions of these sites located on these soil map units may include areas that do not have potential for restoration since those portions were never wetland. This must be determined through field inspection. In using the NWI+ web mapper, the soil for all Type 1 sites can be identified by using the "codes" function, clicking on the applicable dot, and viewing the dropdown table with the soil information.

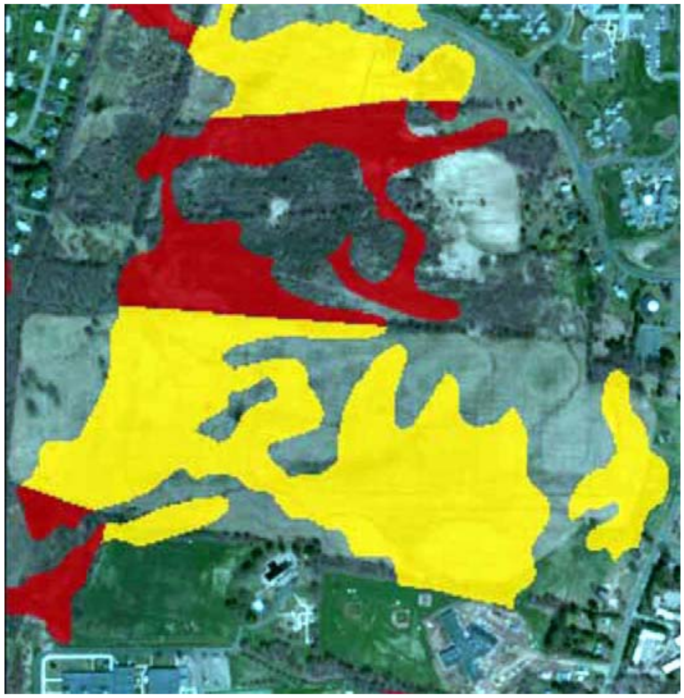
Some sites identified as Type 1 sites may be "missed" wetlands that were not mapped by the 2010 inventory or classified as "P-wet areas" (areas lacking a photointerpretable wetland signature but occurring on a undeveloped hydric soil) in the updated inventory (Tiner 2013) because they were in active agricultural use (Figure 3). Neighboring areas in "natural" vegetation were classified as "P-wet areas." These Type 1 sites may therefore include areas that may actually be farmed wetlands or grazed or mowed wet meadows, but field examination and perhaps hydrologic monitoring would be necessary for positive identification.

Some Type 1 sites may have structures built since 2010. In other cases, a portion of a Type 1 site may have a structure while the majority of the site should not.

Table 1. Hydric soil mapping units used to identify potential wetland restoration sites. The percent of the units that are estimated to be hydric is also given. (Source: USDA)

Soil Mapping Unit Name	**% Hydric**
Brayton-Loonmeadow complex, extremely stony	94%
Brayton loam	94%
Brayton mucky silt loam, 0 to 8 percent slopes, very stony	94%
Bucksport muck	99%
Catden and Freetown soils	100%
Fluvaquents-Udifluvents complex, frequently flooded	61%
Fredon silt loam	90%
Fredon silt loam, cold	90%
Halsey silt loam	98%
Halsey silt loam, cold	90%
Ipswich mucky peat	100%
Leicester fine sandy loam	89%
Limerick and Lim soils	95%
Medomak silt loam	100%
Moosilauke sandy loam	82%
Mudgepond and Alden soils, extremely stony	90%
Mudgepond and Alden soils, extremely stony, cold	80%
Mudgepond silt loam	92%
Mudgepond silt loam, cold	91%
Pawcatuck mucky peat	100%
Raynham silt loam	90%
Raypol silt loam	84%
Ridgebury fine sandy loam	84%
Ridgebury, Leicester, and Whitman soils, extremely stony	92%
Rippowam fine sandy loam	87%
Rumney fine sandy loam	95%
Saco silt loam	82%
Scarboro muck	97%
Scarboro muck, cold	94%
Scitico, Shaker, and Maybid soils	85%
Timakwa and Natchaug soils	100%
Walpole sandy loam	85%
Westbrook mucky peat	100%
Westbrook mucky peat, low salt	100%
Wilbraham and Menlo soils, extremely stony	85%
Wilbraham silt loam	84%
Wonsqueak mucky peat	99%

Figure 3. Type 1 sites identified in Bloomfield: top image showing Type 1 sites (yellow) and P-wet areas (red sites), while bottom image shows soils (code 9 = Scitico, Shaker, and Maybid soils; this soil unit is 85% hydric soil). The P-wet areas are in "natural vegetation" while the Type 1 sites are in agricultural use – pastures or hay fields that may be wet enough to qualify as wetland yet did not have recognizable wetland signature on the aerial imagery used in this survey. Most of the area surrounded by the P-wet area is a palustrine scrub-shrub wetland. (Sources: NWI+ web mapper and USDA web soil survey)



Three dredged material disposal sites were identified as Type 1 sites based on a final review of the interpretation. These represent the more conspicuous areas, so others may exist. They appeared to be inactive due to the presence of vegetation, but they may still be planned for further disposal. Active disposal sites were not identified.

The list of deepwater habitat sites referenced as Type 1 sites is likely to be a conservative listing for the following reason. Other impounded deepwater habitats were designated as “water” by the soil survey. These impoundments were created prior to the recent soil survey. Although not recorded as potential restoration sites in this report, such areas likely include former wetlands and therefore may also qualify as restoration sites. If interested in these sites, simply look for impounded wetlands in the NWI+ database and then review historic imagery or topographic maps to determine their earlier condition.

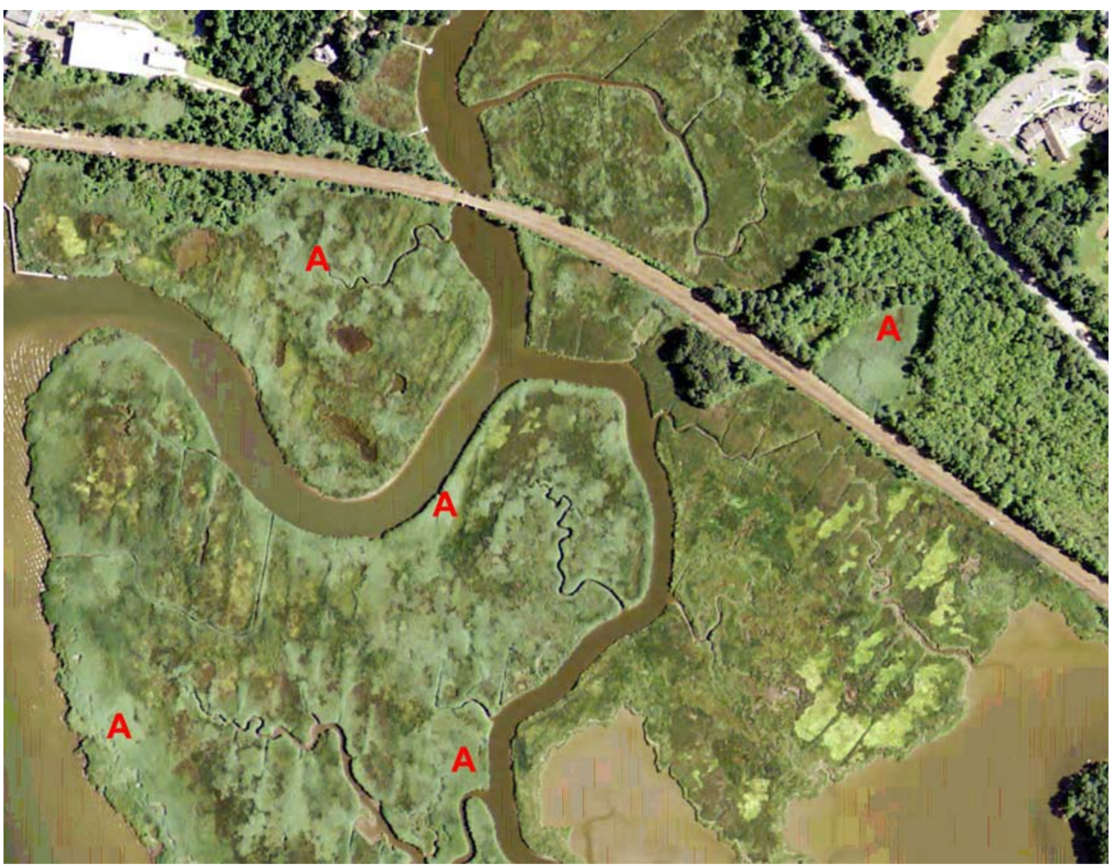
Type 2 Sites

The limitations of interpreting aerial imagery for mapping wetlands are well known (see Tiner 2013, 1999, 1990). Classification errors (omissions and commission errors) can also produce inaccurate results (e.g. small estuarine wetlands with a single ditch or large ones with a few ditches may have not been classified as partly drained). While every attempt was made to limit these errors, it is possible that some such errors remain due in part to the enormous number of polygons mapped, the quality of the available imagery, and the general scope of the project. Also given differences in methods and minimum map unit sizes between the soil survey and the wetlands inventory, all the mapped wetlands do not necessarily fall within a hydric soil map unit.

As mentioned earlier to separate possible created wetlands from natural wetlands for identifying potential Type 2 restoration sites, we consulted the soil survey data and looked for mapped wetlands on hydric soil map units. We established a 50 percent threshold for identifying altered wetlands on hydric soil map units as potential restoration sites. Impacted wetlands that did not meet this requirement were considered to be more likely created wetlands (e.g., created by impoundment) and were not designated as potential restoration sites. While we realize the limitations of the both the soil survey and the updated wetlands inventory at identifying hydric soils and wetlands, respectively, we believe that sites with a greater correspondence between hydric soils and mapped wetlands should have a higher probability of being a naturally formed wetland. The results of this analysis are, therefore, conservative, but should represent the bulk of the state’s wetlands with restoration potential. Similar areas contiguous to these sites that did not occur within a hydric soil map unit may also have potential for restoration, but would require field inspection for validation. Other wetlands identified as partly drained, impounded, farmed, or excavated (i.e., those not occurring within a hydric soil map unit) could also be evaluated in the field for restoration potential in a particular locale.

Invasive species are a significant ecological problem and controlling these species is often an important restoration objective for wetlands and uplands alike (e.g., Capotosto and Wolfe 2007). These non-native species become so abundant that they displace native species. In tidally restricted estuarine wetlands, common reed (*Phragmites australis*) has replaced the low-growing salt marsh grasses with tall grasslands and a thick surface mat of slowly decomposing plant remains. While these wetlands still perform many wetland functions, their fish and wildlife value has been, in most cases, diminished or at least significantly changed for typical salt marsh fauna. Identifying invasive species is often impossible to do on aerial imagery, with some exceptions. Common reed is one exception; large stands of this species can be interpreted. Purple loosestrife (*Lythrum salicaria*) is another exception, but requires imagery captured during the peak blooming period for identification. Other invasives such as multiflora rose (*Rosa multiflora*), glossy or European buckthorn (*Frangula alnus*), and honeysuckles (*Lonicera* spp.) are among the many invasives that require identification through field surveys. The imagery used for this survey did allow identification of large common reed stands but was not suitable for detecting purple loosestrife. Many if not most of the common reed stands were identified as tidally restricted estuarine wetlands or partly drained tidal wetlands; they were not identified as a specific type. Other *Phragmites* marshes can however be identified by accessing the 2010 wetlands geospatial database and looking for the code "EM5" that was used to differentiate common reed stands from other marshes. Alternatively, one could examine aerial imagery for the characteristic signature of common reed (Figure 4).

Figure 4. Aerial image showing photo-signature of common reed (*Phragmites australis*). Pure reed stands are the dull light green areas in the image; several are marked with the letter "A" but many others can be seen, some mixed with other marsh plants.



Other Former Wetlands That May Be Restorable

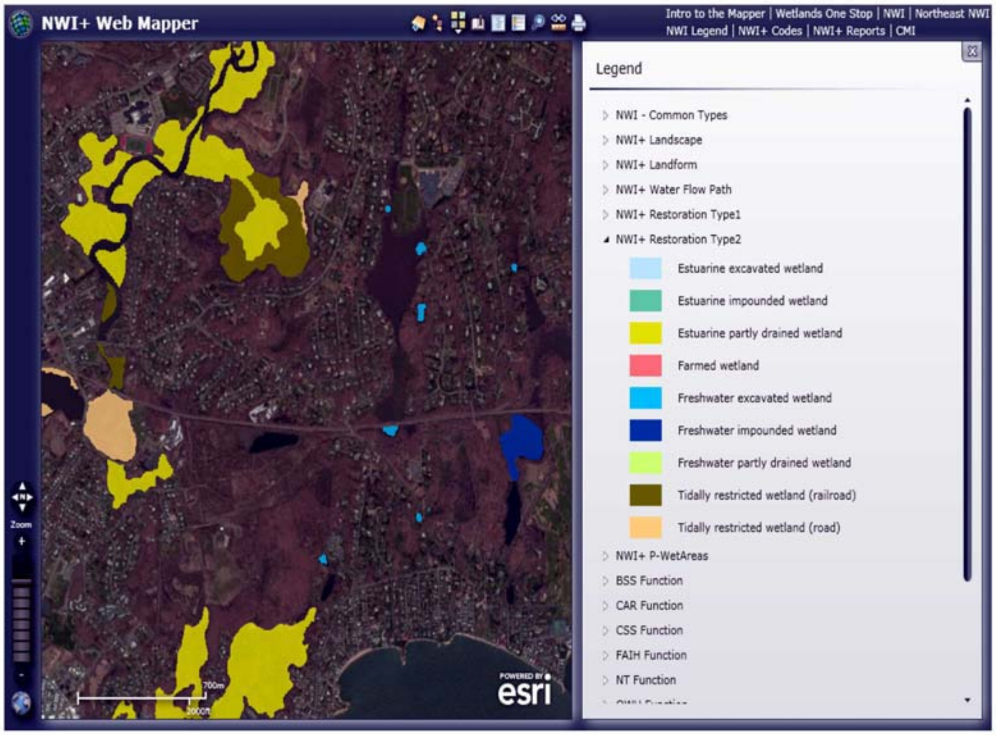
In reviewing the aerial imagery at the conclusion of this project, we noticed that some upland areas along tidal rivers were located in sites that should have been former tidal marshes, although they were not delineated as Type 1 sites because they did not have "hydric soils" mapped by the U.S. Department of Agriculture. Such areas were detected by discontinuities in the distribution of these wetlands along tidal waters. A review of the USDA soil data for specific sites revealed that these areas were mapped as "dumps" or "Udorthents, smooth" which represent fill areas (Figure 5); the soil map unit "Udorthents, urban land complex" is another possibility in some places. Although not identified as Type 1 sites for this inventory, some of these areas have potential for restoration as they once were tidal marshes (their former condition was confirmed by reviewing the 1890s U.S. Geological Survey topographic maps: http://geonames.usgs.gov/pls/topomaps/). They can be identified by examining the aerial imagery via the NWI+ web mapper and looking for discontinuities in the tidal marshes along rivers and then by consulting soil survey data for theses soil map units. The more obvious ones are shown in the Appendix.

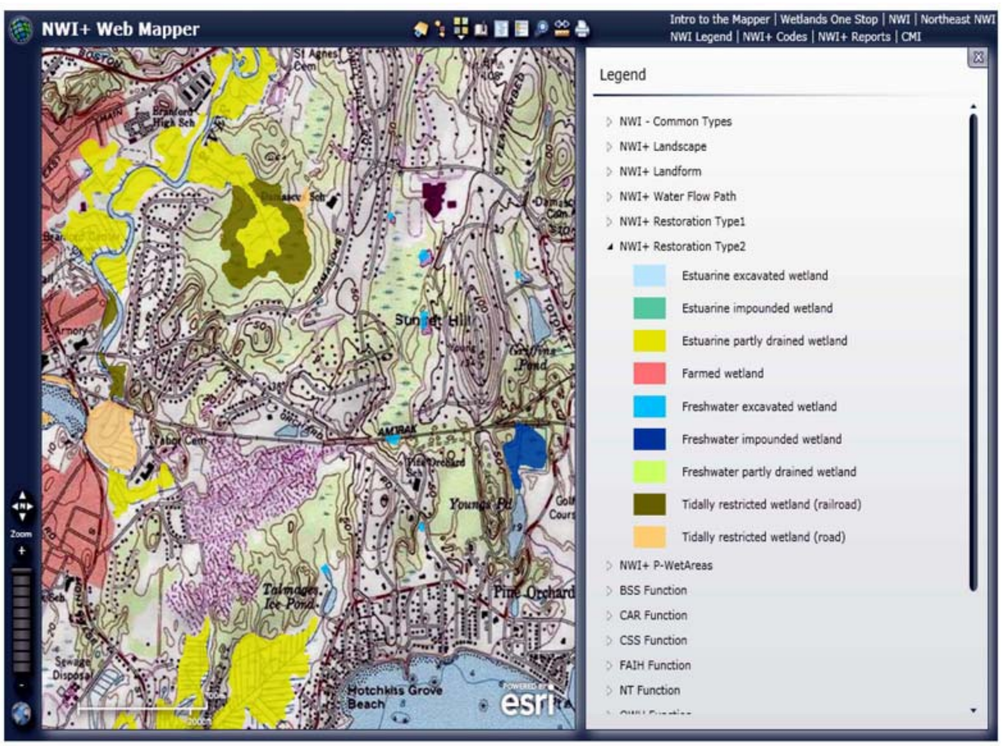
Figure 5. Example of a dump (code 302) built in a tidal wetland (Pine Creek, Fairfield).

Interpretation of Findings

The preliminary nature of this inventory is emphasized. The designated sites or portions of these sites should have potential for restoration. Whether or not they are practical sites depends on many factors including the current use of the sites, the interest of the landowner, the work required for restoration, project budgets, and agency/organization priorities. It is obvious that some sites will be easier to restore while others would be more difficult and costly. Nonetheless, the inventory provides a large population of sites for restoration specialists to consider. They can prioritize sites based on their objectives.

Figure 6. Examples of an online map showing potential Type 2 restoration sites for the Branford area: on aerial image (top) and on U.S.Geological Survey topographic map base (bottom). (Source: Preliminary data posted on NWI+ web mapper)





RESULTS

Distribution of Restoration Sites

The location and type of potential wetland restoration sites can be displayed via the NWI+ Web Mapper on the Association of State Wetland Managers' website - "Wetlands One-Stop Mapping" (http://aswm.org/wetland-science/wetlands-one-stop-mapping). This website is a cooperative effort between the Association, Virginia Tech's Conservation Management Institute, and the U.S. Fish and Wildlife Service to display NWI+ data, associated reports, and other wetland mapping data and information. The NWI+ web mapper contains a number of data layers, four of which pertain to the restoration inventory:

- *NWI+ Restoration Type1* – this layer identifies former wetlands (now nonwetlands) that are in a land use where wetland restoration may be possible. Type 1 restoration sites should be former wetlands that were converted to either "developable land" by drainage and/or filling or deepwater habitats by impoundment (diking) or excavation (dredging).

- "*NWI+ Rest Type 1 Soil Codes*" – places dots on map to access information on soil properties for Type 1 sites.

- *NWI+ Restoration Type2* – this layer shows existing wetlands that have been impaired to a degree that affects their ability to function like an undisturbed natural wetland. The color-coded types shown on the mapper focus on one type of impact; recognize that some wetlands have multiple impacts (e.g., estuarine marsh that is tidally restricted and ditched).

- "*Wetland Codes*" – places dots on the map to access information on wetland classifications that contain information on wetland impairments; in wetland code – look for the following special modifiers: d (partly drained/ditched), f (farmed), h (diked/impounded), and x (excavated) and in the LLWW code, look for: td (tidally restricted/road), tr (tidally restricted/railroad), or to (tidally restricted/other). in the LLWW code).

All layers can be viewed simultaneously since there should be no overlap between Type 1 and Type 2 sites. Simply click on the box for each layer and the layers will become active. Click on the "Legend" icon to view the applicable legends (may need to scroll down the list of legends to find the ones for the Restoration Type1 and Type2 layers). Figure 6 shows an example of Type 2 sites on two different base maps (an aerial image and a U.S. Geological Survey topographic map).

Type 1 Potential Restoration Sites (Former Wetlands)

Roughly 18,000 acres of former wetland were identified as dryland sites that may be suitable for restoration, while 753 acres of former wetland are now underwater and may have potential for restoration (Table 2). The dryland sites typically represent effectively drained former wetlands, although some may represent farmed wetlands on floodplains that were not mapped as "farmed wetland" as they did not show any indication of wetness on the 2011 imagery. Filled sites were extremely limited as nearly all these sites are developed. Former tidal marshes that were filled in the past have been converted to residential or commercial development. Three filled tidal marshes were disposal areas for dredged material - one in Westbrook at the mouth of the Patchogue River, another at the mouth of the East River in Guilford and the other in Branford along the Branford River (Figure 7). Others may exist but they were not mapped. Fill sites used as dumps and other disposal areas were not listed as Type 1 sites, but some prominent ones in tidal wetlands are shown in the Appendix. The extent of former wetlands that are now deepwater habitats (753 acres) is conservative as they are the ones that were located on hydric soil map units. As mentioned in the previous section, many other impoundments were likely created from wetlands yet mapped as "water" on the soil survey. Although not highlighted in this inventory, they too represent potential sites for re-establishment of wetlands.

Figure 7. Example of dredged material disposal site identified as a Type 1 site along the Branford River. Subject area is green area in center of photo.

Table 2. Acreage summary of potential Type 1 restoration sites for Connecticut. Anderson et al. (1976) code is given for dryland sites, while general map code is given for deepwater sites. <u>Note</u>: Sum of subcategories is greater than deepwater category because some areas are affected by more than one impact (e.g., impounded and tidally restricted).

Current Condition of Site (codes)	**Acreage**
Agriculture (200; e.g., cropland or pasture)	17,597.7
Barren Land (700; includes vegetated disposal areas)	432.8
Subtotal (now dryland)	***18,030.5***
Estuarine Water (E1UBL_)	229.5
Impounded Estuarine Water (E1UBLh)	*65.1*
Excavated Estuarine Water (E1UBLx)	*14.2*
Estuarine Water Tidally Restricted by Road (E1UBL and td)	*107.6*
Estuarine Water Tidally Restricted by Railroad (E1UBL and tr)	*118.5*
Lacustrine Water impounded (L1UBHh)	482.2
Riverine Water (R_UB_)	41.6
Impounded Riverine Water (22.3 -R2UBHh and 2.2-R2ABHh)	*24.5*
Excavated Riverine Water (R1UBHx)	*1.0*
Tidally Restricted by Road (R1UBV)	*16.1*
Tidally Restricted by Railroad (R2ABHh)	*2.2*
Subtotal (now deepwater habitat)	***753.3***
Total Type 1 Sites*	**18,783.8**

*Acreage total does not include filled sites: see Appendix for more prominent examples of the potential Type 1 sites (dumps and dredged material disposal areas).

Type 2 Potential Restoration Sites (Existing Impaired Wetlands)

Slightly more than 22,500 acres or about 10 percent of the state's wetlands were designated as having potential for restoration (Table 3). These wetlands have been altered from that of a natural wetland of that type by one or more human actions (e.g., ditching, diking, excavation, farming, or by roads or railroads). Consequently, their functions may have been diminished to some degree. These wetlands fall into four categories: partly drained wetlands, farmed wetlands, impounded wetlands, and tidally restricted wetlands. Some wetlands have multiple impacts. Most of the Type 2 restoration sites were affected by either ditches (partly drained; Figure 8) or dikes (impounded). These two situations accounted for 84 percent of the Type 2 sites. Twenty percent of the sites were tidally restricted wetlands, with most of these affected by roads.

Table 3. Acreage summary of Type 2 restoration sites for Connecticut. These sites are impacted wetlands or portions of impacted wetlands that were located on hydric soil map units. Note: The total is less than the sum of subcategories because some wetlands are affected by multiple impacts (e.g., partly drained, impounded and tidally restricted by road). Also there nearly 4,300 acres of estuarine wetlands dominated or co-dominated by common reed (*Phragmites australis*) in the state (Tiner 2013) and many of these fall into one or more of the listed categories.

Current Wetland Condition	**Acreage**
Partly drained	10,331.9
Partly drained estuarine wetland	*7,050.0*
Partly drained/impounded estuarine wetland	*114.2*
Partly drained palustrine wetland	*3,166.1*
Partly drained/impounded palustrine wetland	*1.6*
Farmed	29.4
Impounded	8,557.4
Impounded	*8,441.6*
Impounded/partly drained	*115.8*
Excavated	2,406.0
Tidally restricted estuarine wetlands	4,351.2
Tidally restricted by railroad	*1,032.1*
Tidally restricted by road	*3,277.8*
Tidally restricted by other development	*39.3*
Tidally restricted, now freshwater wetland	58.4
Total for All Sites Combined	**22,533.3**

Figure 8. The hydrology of nearly all of state's tidal marshes has been adversely impacted by ditches; this image shows ditched marshes in Guilford. Also visible are excavated former wetlands forming the marina boat basin and filled areas associated with the marina.

DISCUSSION

During the past two decades there have been increased efforts to restore Connecticut's wetlands. Most of the projects involve rehabilitating or re-establishing tidal wetlands. Nearly all of the state's tidal wetlands were ditched at one time or another (Figure 8), while others have had their connection to tidal waters limited by road or railroad crossings or by development. Reviving more natural hydrology and controlling common reed to encourage growth by native species are prime restoration objective. Re-establishment projects involve removal of fill and reconstructing a drainage network like was done at Stewart B. McKinney National Wildlife Refuge in Stratford and Hammonasett Beach State Park in Madison (Figures 9 and 10).

Figure 9. Salt marsh restoration project at Stewart B. McKinney National Wildlife Refuge: pre-construction condition (2004; top left; CTDEEP), during construction (2008; top right; CTDEEP) and restored marsh in 2011 (bottom). Today the restored area looks like the contiguous natural marsh.

Figure 10. Restoration of a tidal marsh at Hammonasett Beach State Park, Madison: before (top – filled with dredged material from Clinton Harbor in the past), during (middle) and after (bottom) restoration in 2011. (Top two photos: CTDEEP)

If looking for reference wetlands for tidal wetland restoration, we came across few examples of nonditched tidal marsh: one located in Milford at the mouth of the Housatonic River (Figure 11), a pair of marshes at the mouth of the Black Hall River in Lyme (Figure 12), and portions of the Lordship Cove marshes in Stratford (Figure 13).

Figure 11. Nells Island marsh (Charles E. Wheeler Wildlife Management Area) at the mouth of the Housatonic River (Milford). Note the dendritic creek pattern.

Figure 12. Two nonditched tidal marshes at the mouth of the Black Hall River (Lyme). Note the abundance of ponds and pools in these marshes (brown-colored) compared to the ditched marshes (green) nearby.

Figure 13. Portions of the Lordship Cove marshes in Stratford were never ditched; some sections were ditched or cut off by roads and others filled. (See Appendix, Figure A-3)

Restoration activities also involve nontidal wetlands. Although less effort has been dedicated to these wetlands, there are thousands of acres that are suitable for restoration. Re-establishment would typically involve restoring hydrology and perhaps microtopography to effectively drained lands (former wetlands) that are now in agricultural use. Other Type 1 restorations (re-establishment) would involve removal of fill material or dams. Rehabilitation of existing impaired wetlands could be accomplishing by restoring more natural hydrology to partly drained or diked/impounded wetlands or by rebuilding elevations in excavated wetlands (ponds) to a level that would support wetland vegetation. Controlling invasive species like common reed and multiflora rose by various means including use of herbicides offer many other opportunities for restoration of native plant communities.

The U.S. Fish and Wildlife Service's Partners for Fish and Wildlife Program is working with the State of Connecticut, other agencies (e.g., USDA Natural Resources Conservation Service), organizations (e.g., Ducks Unlimited and land trusts), and local governments on various restoration and wetland enhancement initiatives (contact: USFWS, Stewart B. McKinney National Wildlife Refuge, Westbrook or CTDEEP, Office of Long Island Sound Programs and Inland Water Resources Division, Hartford for information).

SUMMARY

This inventory of potential wetland restoration sites was performed mainly by comparing soil survey data with 2010 wetlands inventory data. The analysis identified two basic types of restoration sites: former wetlands lacking structures (buildings and other structures; Type 1 sites = re-establishment) and impacted wetlands whose functions may be reduced to some degree (Type 2 sites = rehabilitation). Restoring the former sites would result in a gain in both wetland acreage and function while rehabilitating the latter may produce wetlands with functions at levels more typical of undisturbed wetlands.

A total of 18,784 acres of Type 1 sites were identified statewide, whereas roughly 22,500 acres of Type 2 sites were mapped. Most of the Type 1 sites were hydric soils that are now used as pasture or cropland and believed to be effectively drained. The Type 2 wetlands represent about 10 percent of the state's wetlands. Eighty-four percent of these sites were either partly drained due to ditching or impounded by dikes or dams. The location of these restoration sites can be viewed using the NWI+ web mapper which is accessed online at: http://aswm.org/wetland-science/wetlands-one-stop-mapping. Some additional sites – former tidal wetlands that were filled (dumps or dredged spoil areas) – are shown in the Appendix of this report.

The preliminary nature of this inventory is emphasized. The designated sites may have potential for restoration. Whether or not they are practical sites depends on many factors including the current use of the sites, landowner interest, the work required for restoration, project budgets, and agency/organization priorities. It is obvious that some sites will be easier to restore while others would be more difficult and costly (e.g., dammed and excavated sites and abandoned dumps). This inventory provides a large population of sites for restoration specialists to consider.

ACKNOWLEDGMENTS

Several people have contributed to this report. The U.S. Fish and Wildlife Service's National Wetlands Inventory Program, Northeast Region oversaw all aspects of this project, with work coordinated by Ralph Tiner. Bob Gilmore was project officer for the Connecticut Department of Energy and Environmental Protection (CTDEEP). Image analysis, database development, and production of data layers for posting on the web were performed by staff at Virginia Tech's Conservation Management Institute under the direction of Dr. Scott Klopfer and Kevin McGuckin: Jason Herman, Nicole Fuhrman, Brian Diggs, and David Orndorff. Jason Herman compiled the statistical spreadsheets used to summarize the study's findings for this report and made final edits to the geospatial database. Ralph Tiner reviewed those statistics as well as some of the findings, identified other possible Type 1 sites (referenced in the Appendix), and prepared the report with assistance from Kevin McGuckin and Jason Herman. Roger Wolfe (CTDEEP) provided photos for use in this report, while Gina Jones (FWS) prepared the cover. The draft report was peer reviewed by Bill Wilen and JoAnn Mills (FWS) and Bob Gilmore (CTDEEP).

REFERENCES

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. A Land Use and Land Cover Classification System for Use with Remote Sensor Data. U.S. Geological Survey, Reston, VA. Professional Paper 964. http://landcover.usgs.gov/pdf/anderson.pdf

Capotosto, P. and R. Wolfe. 2007. Controlling *Phragmites australis* in Connecticut's fresh and salt-water wetlands. Connecticut Department of Environmental Protection, Wildlife Division, Wetland Habitat and Mosquito Management Program, Hartford, CT. http://www.ct.gov/deep/lib/deep/wildlife/pdf_files/habitat/PhragControl.pdf

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. *Classification of Wetlands and Deepwater Habitats of the United States.* U.S. Fish and Wildlife Service, Washington, DC. FWS/OBS-79/31. http://library.fws.gov/FWS-OBS/79_31.pdf

Tiner, R.W. 2013. *Wetlands and Waters of Connecticut: Status 2010.* U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA. With technical support from the Conservation Management Institute, Virginia Tech, Blacksburg, VA. http://aswm.org/wetlandsonestop/report_wetlands_of_connecticut_status.pdf

Tiner, R.W., J. Herman, and L. Roghair. 2013. *Connecticut Wetlands: Characterization and Landscape-level Functional Assessment.* Prepared for the Connecticut Department of Environmental Protection, Hartford, CT. U.S. Fish and Wildlife Service, Northeast Region, Hadley, MA. http://aswm.org/wetlandsonestop/ct_characterization_functions.pdf

Tiner, R.W. 2011. *Dichotomous Keys and Mapping Codes for Wetland Landscape Position, Landform, Water Flow Path, and Waterbody Type Descriptors: Version 2.0.* U.S. Fish and Wildlife Service, National Wetlands Inventory Program, Northeast Region, Hadley, MA. http://digitalmedia.fws.gov/cdm/ref/collection/document/id/1324

Tiner, R.W. 1999. *Wetland Indicators: A Guide to Wetland Identification, Delineation, Classification, and Mapping.* Lewis Publishers, CRC Press, Boca Raton, FL.

Tiner, R.W. 1990. Use of high-altitude aerial photography for inventorying forested wetlands in the United States. Forest Ecology and Management 33/34: 593-604.

U.S. Department of Agriculture. 2008. *Soil Survey of the State of Connecticut*. Natural Resources Conservation Service in cooperation with the Connecticut Agricultural Experiment Station, the Storrs Agricultural Experiment Station, and Connecticut Department of Environmental Protection. http://cteco.uconn.edu/docs/usda/connecticut.pdf

APPENDIX.

Examples of old fill and dump sites that may have restoration potential (possible Type 1 restoration sites). Restoration would require removal of fill and re-creation of a tidal creek network in addition to addressing any issues regarding the existence of hazardous or other waste materials.

Figure A-1. Former dump (code 302) now part forest and meadow built at least in part from tidal marsh along Pine Creek in Fairfield (see 1892 USGS topographic map below). Also note that excavated waterbody and exposed soil with buildings to right of dump was also tidal marsh. (Source: USDA web soil survey)

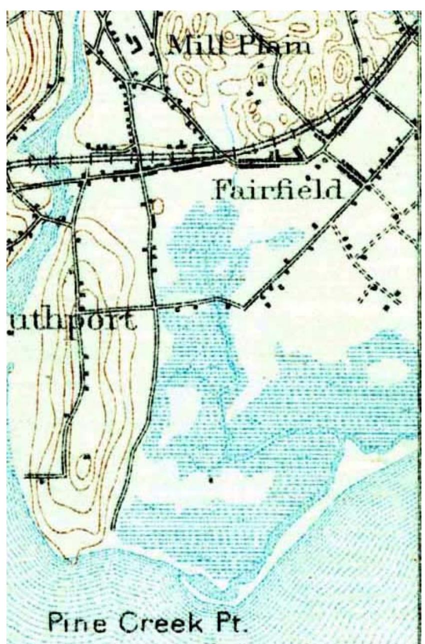


Figure A-2. Ash Creek, Fairfield County. Soil type 308 (Udorthents, smooth) is a fill site that may have impacted tidal marsh (see 1891 USGS topographic map below). It is located above the marina which may also have been constructed in tidal wetland. (Source: USDA web soil survey)

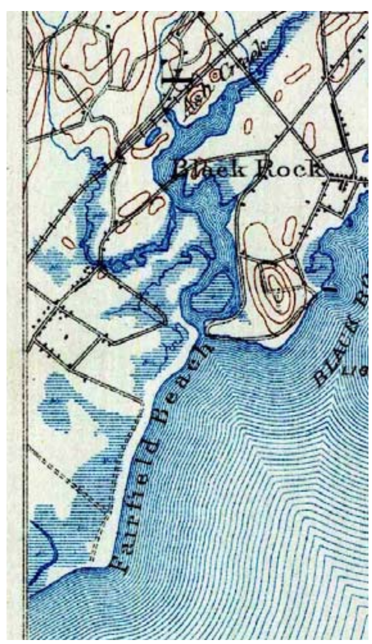


Figure A-3. Lordship Cove, Stratford in Fairfield County includes the Stewart B. McKinney National Wildlife Refuge. Originally the area contained one of the largest salt marsh complexes in the state, but much filling has taken place since 1891 (see USGS map below). Soil code 308 (much of it behind the white line) represents fill sites. Today this area is an active site for salt marsh restoration. (Source: USDA web soil survey)

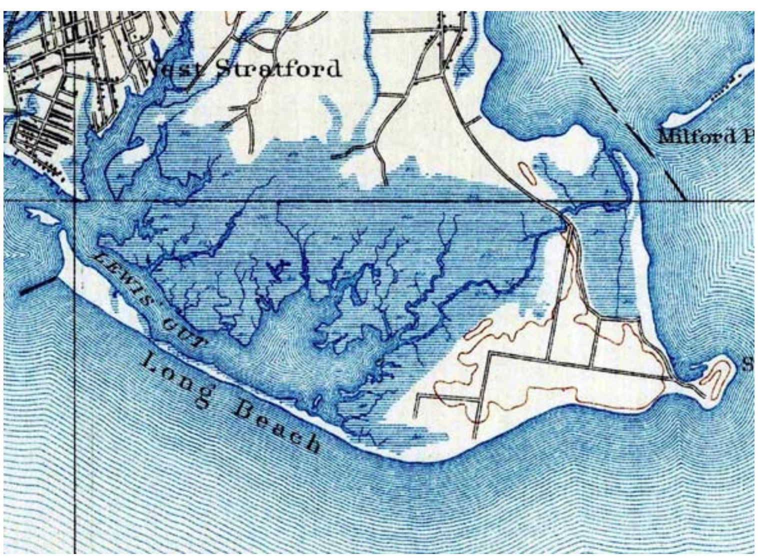


Figure A-4. Former dump (code 302) along Great Creek in Milford (Silver Sands State Park) that was built in tidal marsh (see 1891 USGS topographic map below). (Source: USDA web soil survey)

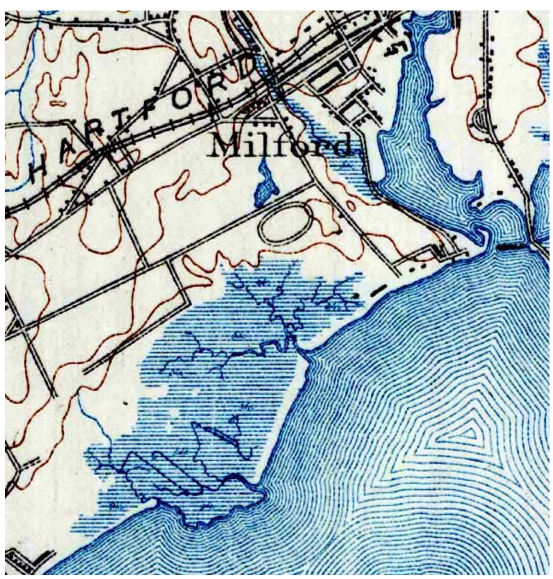
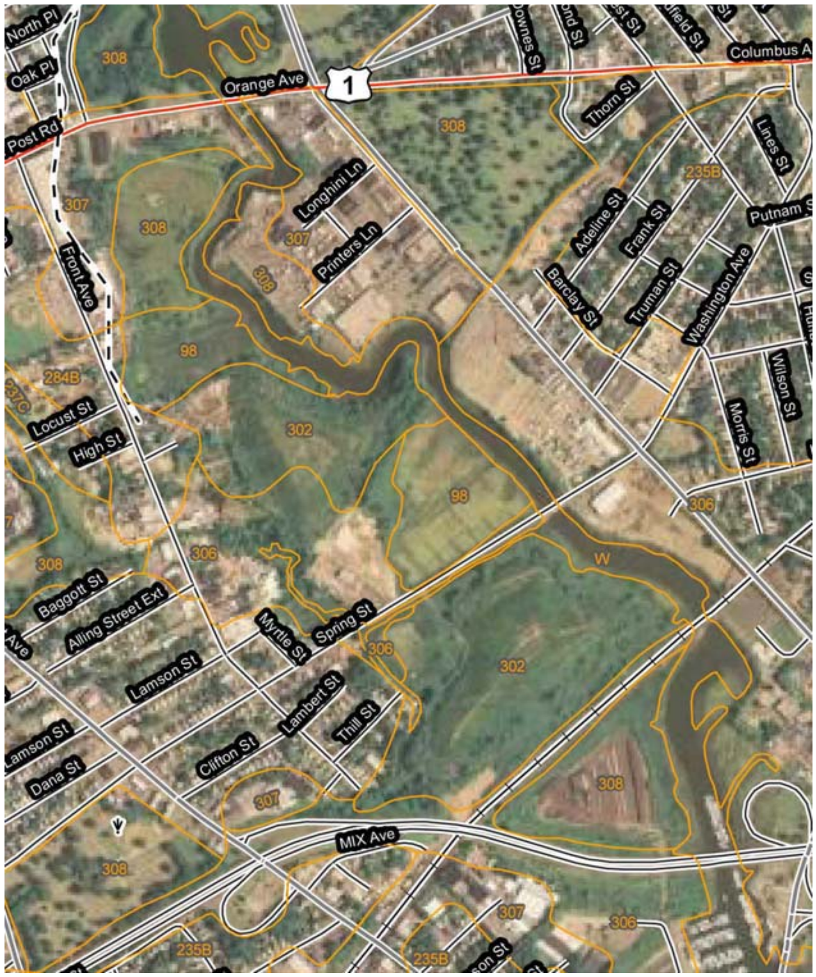


Figure A-5. Five sites (codes 308 and 302 – filled land and dumps) along left bank of West River in West Haven that represent old fill sites in former tidal marshes (see 1892 USGS topographic map below). The lower site is still active (brown triangular area). (Source: USDA web soil survey)



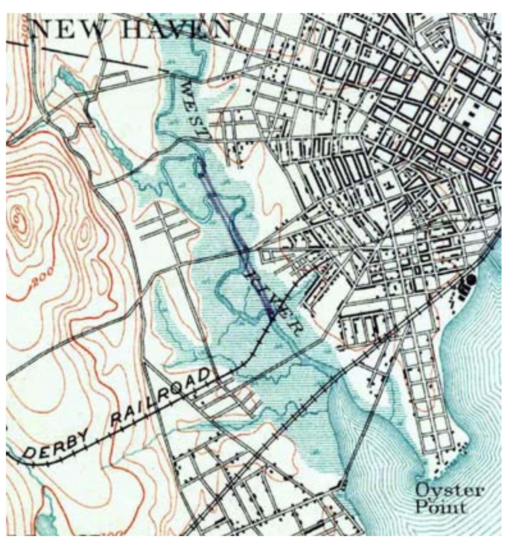


Figure A-6. Fill site (code 308) that includes some former tidal marsh located along the West River in Guilford (see 1893 USGS topographic map below); also note marina constructed from tidal marsh. (Source: USDA web soil survey)