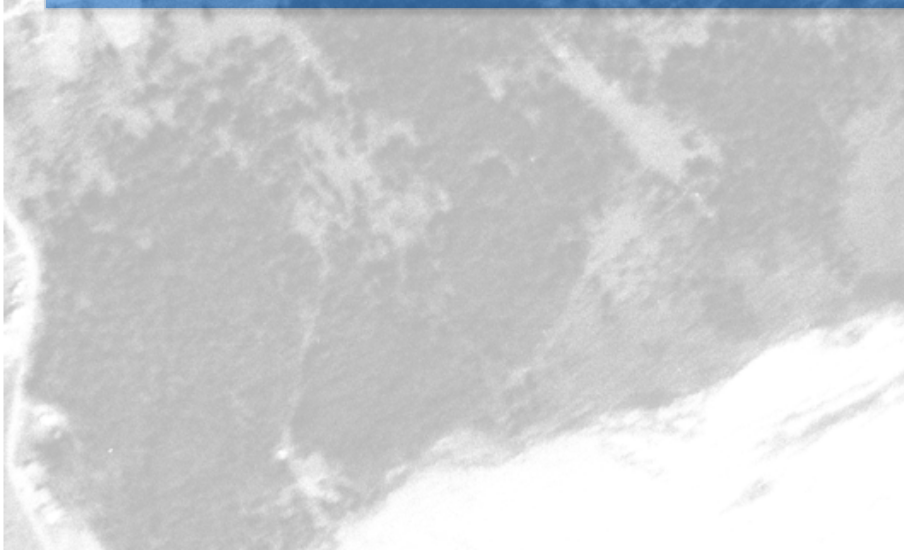
Extent of Wetland Fill by Wetland Type in the Hydrologic Units Surrounding the Population Centers of the Kenai Peninsula Borough



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SUMMARY

A comparison of 1950’s historic aerial imagery to 2012 & 2013 aerial imagery and field verification identified 652 separate wetland fills covering 1631 acres in six selected HUCs (Hydrologic Unit Codes) on the Kenai Peninsula. The HUCs selected encompass the population centers of Homer, Kenai, and Soldotna. Overall, 3.44% of wetland area has been filled in these HUCs. Some types of wetlands in some HUCs have been filled at a disproportionately higher rate.

Substantial declines in stream quality may be expected after more than five percent of wetlands in a boreal watershed have been filled. Overall, less than 1% of wetlands in the Island Lake HUC and less than 2% of wetlands in the Longmere Lake and Soldotna Creek HUCs have been filled. However, fill in wetlands in the HUC surrounding the cities of Kenai and Soldotna covers 3.55% of their total area. Moreover, in the HUC surrounding Homer more than 6% of all wetlands have been filled by area (800 of the 12,041 acres of wetlands). The Diamond Creek-Frontal Cook Inlet HUC encompassing Homer spans from near the mouth of the Anchor River through the City of Homer and eastward nearly to Fritz Creek (25,062 acres).

Wetlands on the Kenai Peninsula have been classified into different geomorphic types. Geomorphology is the study of the shape of the land: what forces created a landform and how the landform changes through time. Examples of different types of landforms are river-valley bottoms, steep-sided depressions, and flat lakebeds. Elements of green infrastructure, the valuable infrastructure provided for free by nature to human society, can vary depending on geomorphic type. Therefore, fill placed disproportionately in specific types of wetlands may cause losses of certain elements of green infrastructure. Wetland fill is not distributed evenly across different geomorphic types of wetlands.

A total of six geomorphic types of wetlands in the different HUCs have had at least five percent of their area filled. In the north, wetlands in the Island Lake HUC, which encompasses the area north of Nikiski, have been relatively unimpacted by fill: 1.2% of Riverine wetlands have been filled (0.52 of 45.3 acres) and less than 1% of any other type of wetland has been filled there. In the Longmere Lake HUC, which covers the area between Mackey Lakes and Sterling, 3.5% of Drainageway wetlands have been filled (14.1 of 410.7 acres), and less than 1.2% of any other type of wetland has been filled. In the Sports Lake HUC, which encompasses the cities of Kenai and Soldotna, 6.4% of Lakebed wetlands have been filled (411 of 6411 acres) and less than 3% of other types have been filled. In the Salamatof Creek HUC, which extends from just north of Kenai to Nikiski, nearly 5% of Riverine wetlands (1.3 acres of 26.3 acres) and 20% of Discharge Slope wetlands have been filled (43.7 of 222.3 acres).

Around Homer, wetland fill is more prevalent. More than 5% of Kettles in the HUC surrounding Homer have been filled (104 of 2047 acres), and over 20% of Depressions (25 acres of 121 acres) and 15% of Discharge Slope wetlands have been filled (547 acres of 3600 acres).

Therefore, because a substantial amount of valuable green infrastructure may have already been lost in HUCs where more than 5% of the area of one or more geomorphic types of wetlands have been filled, either no additional filling should be permitted, or compensatory mitigation should be required in the following types of wetlands within these HUCs:

- Sports Lake
  - Lakebed wetlands
- Salamatof Creek
  - Discharge Slopes, and Riverine wetlands
- Diamond Creek - Frontal Cook Inlet
  - Depressions, Discharge Slopes, and Kettles

Green infrastructure is the patchwork of undisturbed soils and vegetation that provides services such as flood protection, clean water, and fish habitat to society. Without careful management, this green infrastructure will continue to deteriorate until expensive measures will be required to maintain the quality and quantity of surface and ground water in these HUCs.

INTRODUCTION

Wetlands are important components of green infrastructure: the valuable infrastructure that the natural environment provides to society. Federal law protects some of this infrastructure by requiring that a permit be obtained before a wetland can be filled. An assessment of valuable infrastructure, which includes wildlife habitat, streamflow quantities, and clean water, may be required before a permit can be obtained. An assessment should evaluate cumulative impacts to wetland infrastructure (also known as wetland functions) throughout a watershed (HUC). The Kenai Peninsula Fish Habitat Partnership also recognizes that the cumulative impacts of filling wetlands can reduce their value to fish, which are an important resource to the citizens of the Kenai Peninsula Borough. To protect the value of wetlands to fish, the Partnership has formulated Conservation Strategies which state that the threat of

> loss of direct surface water aquatic habitat connectivity to adjacent wetlands and other off channel habitat, loss or disruption of groundwater patterns, loss of primary nutrient input (grass, leaves, insects, etc.), increases in impervious surfaces.

The conservation strategies state that these threats should be “minimized and managed”. Filling wetlands creates such loss of habitat connectivity, it disrupts ground water flow, and it increases the cover of impervious surfaces. If a wetland assessment identifies unavoidable impacts to wetland green infrastructure, compensation to mitigate for the lost functions may be required. The goal of compensatory mitigation is to maintain components of wetland infrastructure, such as stream flow quantity and quality, which are important characteristics of fish habitat.

Different types of wetlands are often filled at different rates because development activity is concentrated in a subset of possible locations, such as along shorelines. These different types of wetlands in different locations function differently to provide differing degrees of green infrastructure. Therefore, preventable losses of valuable infrastructure can occur even if less than two percent of all wetlands are filled within a HUC.

The amount of loss due to fill is an important component of a cumulative-impacts analysis. Knowledge of cumulative impacts to different types of wetlands will inform managers when they are determining where and when compensation to mitigate these preventable losses should be required. These types of determinations are currently being made in the absence of reliable estimates of wetland losses due to placement of fill. No formal assessment of wetland losses has ever been made on the Kenai Peninsula.

Here I quantify the total acreage of wetland fill since the era of modern settlement in six HUCs surrounding the population centers of the western Kenai Peninsula, including the acreage of fill by wetland type and HUC (Figure 1).

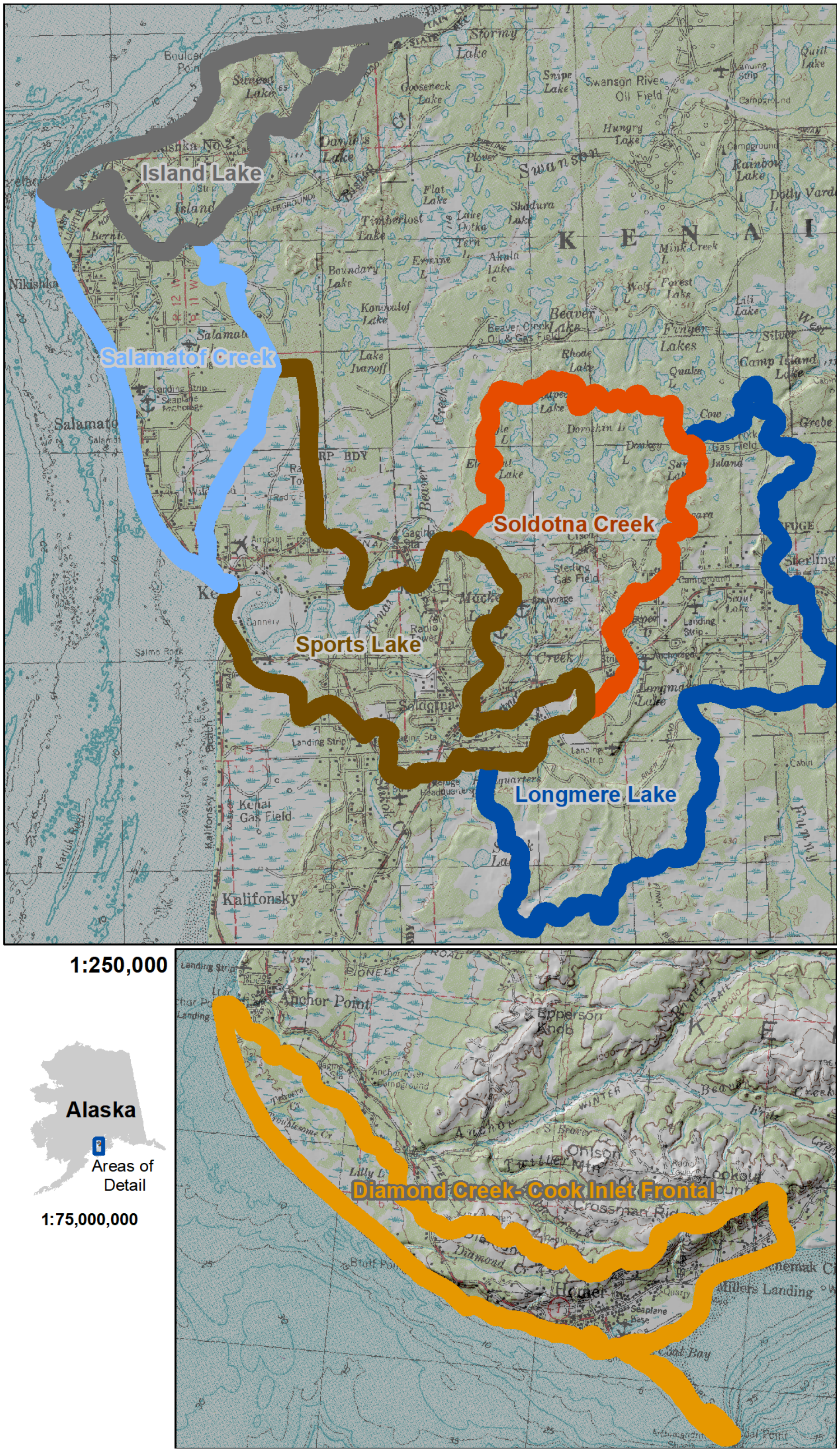

Figure 1. The six HUCs on the Kenai Peninsula, Alaska where the extent of wetland fill was quantified. Five of the HUCS surround the cities of Kenai, Nikiski and Soldotna in the north (Island Lake, Salamatof Creek, Sports Lake, Soldotna Creek and Longmere Lake), and one surrounds the City of Homer, in the south (Diamond Creek – Cook Inlet Frontal) (outlined in colors, total area = 170,472 acres).

The types of wetlands that have been filled were classified according to the Cook Inlet Classification (Gracz & Glaser 2016), a system that classifies wetlands by geomorphic type and seasonal variation of water levels. The analysis was performed by using wetland mapping that was completed in 2006, along with comparing high-resolution imagery acquired in 2012 and 2013 to the oldest imagery available for the area, which was acquired in 1950-52. This assessment of wetland fill will help inform a cumulative impacts analysis as part of permitting decisions, and, if considered, should help slow or halt the loss of important wetland fish habitat in the Kenai Peninsula Borough.

METHODS

I used wetland mapping data, LiDAR, and comparisons of modern and historical aerial photography to guide the creation of polygons surrounding areas of wetland fill. Wetlands mapped with the Cook Inlet Classification (Gracz & Glaser 2016) were used to help guide the comparisons among imagery acquired in 2012 and 2013, with that acquired in 1950-52.

The objective of these methods was to produce the most reliable calculation of the area of wetland lost due to placement of fill by human activity during the era of modern settlement. The newest imagery for the project area was acquired in May 2012 (northern area) and June 2013 (Homer area) at a single pixel resolution of 2.5 feet. The imagery was used with a hillshade created from a 4-foot resolution digital elevation model obtained in 2008 using Light Detection and Ranging (LiDAR). The hillshade was overlain on the imagery and made partially transparent, in order to better visualize the hydro-geomorphic setting of wetlands on the landscape. The Cook Inlet Wetland mapping, especially where wetland polygons had previously been field verified, guided wetland determination.

The oldest imagery obtained that covers the entire project area was acquired in three different years: 1950, 1951, and 1952. Scans of these aerial photographs were downloaded from the US Geological Survey from: https://earthexplorer.usgs.gov. The imagery from 1950 was flown on four different dates: 28 June, 5 July, and 5 and 8 August. The 1951 photography was flown on 25 June and 5 July. This earlier photography covers the northern HUCs. Aerial photography covering the southern HUC, around Homer, was flown on 9 and 15 August of 1952. The different dates of the imagery were taken into account when interpreting wet areas. Photography acquired in June, for example, generally shows wetter conditions due to recent snowmelt.

Geo-rectification of older imagery

The scanned photos were geo-rectified, or more accurately, rubber-sheeted, into real-world coordinates using the geo-rectification tool in ArcGIS 10.1. This tool requires the user to accurately locate matching control features on both old and new imagery. The new imagery employed for this purpose was the seamless 2012 and 2013 fixed-wing aerial imagery acquired by the Kenai Borough and projected into State Plane Alaska Zone 4 coordinates using the NAD 83 datum. In the north, around Nikiski, Kenai and Soldotna, the photography was almost entirely acquired on 16 May 2012, except for two frames in the extreme southeastern portion of the Longmere Lake HUC which were flown a day later, on 17 May. Around Homer, the aerial photography for the Diamond Creek - Cook Inlet Frontal HUC was flown the following year, over four days, from 7-10 June 2013. These flights early in the growing season not long after the period of snowmelt are well-suited for wetland mapping because the water table is high, the ground is minimally obscured by fast-growing vegetation, and the sun angle is high enough to limit shadows.

To rectify the older imagery, at least three matching control points are required to use a linear transformation to align the un-rectified photo with real-world coordinates. A linear transformation may be sufficient when the topography is almost completely flat, and when the altitude of acquisition is high, such as imagery acquired from satellites. However, where hills are present and flight altitudes are sub-orbital, a more complex method of transformation is needed to produce an accurate alignment over the extent of the photo. Therefore, a second-order transformation was used, which requires at least six matching control points. Higher-order transformations are feasible, but they were avoided, because they required more matching control points. There are at least two dangers in using too many control points: 1) the difficulty in locating points that reliably align between the years, thus the potential for introducing increasing amounts of error in positional accuracy, and 2) bias, if the points that do align are located in unrepresentative areas of the photo. This bias will produce excessive distortion in regions of the photo that are under-represented.

For the reasons described above, between 6-9 control points were used with a second-order transformation to rectify all of the older scanned photos. Points were as evenly distributed as possible across the scanned photo, and points near the edges of the photos, where spherical aberration due to the camera lens is greatest, were avoided. Common types of features used to match the older scanned aerial photography to the more recent fixed-wing imagery were points along the margins of lakes and peatlands where the transition was steep (minimizing differences due to differing water levels); small upland tree islands in larger peatlands; small open depressions in the forest; bridge crossings; and the projected centerlines of road intersections. Points along stream and river courses were avoided because, upon careful examination, stream courses almost always had shifted between older and newer images. Even with care, the aligning of control points was inexact, and precisely geo-rectified images were not obtained. However, the relatively small errors in geo-rectification should not be sufficient to substantially bias the calculation of the area of wetlands filled at the nominal mapping scale of 1:12,000.

Each historic aerial photo was visually examined while control points were being selected so that distortion could be minimized before the transformation was committed to a geo-rectified file. Alignment was never perfect, and although points match very well over much of the area covered, errors of 10-20 meters in real-world units should be expected in some areas. After rectification, the historic aerial photos were clipped to discard edges and occasionally to the small area of the photo needed to fill a gap in coverage. Control points were distributed only around the area of the photo that was actually needed on these smaller gap-filling portions of the original images.

<u>Mapping of wetland fill polygons</u>

Once the older imagery was rubber-sheeted, it was layered in ArcGIS 10.1 underneath the 2.5-foot resolution fixed-wing imagery acquired in 2012 and 2013, along with the hillshade of the 2008 LiDAR data, and the wetland mapping. The extent of the project area was systematically examined at a scale of 1:4000 or greater (i.e. higher zoom level) to identify fill that had been placed in wetlands. Typically, the 2.5-foot resolution imagery was sufficient by itself to show areas that had been filled. Often, the LiDAR hillshade aided evaluation of wetland extent by revealing sharp breaks in slope and clear extents of fill pads. The areas of fill were primarily road crossings, airstrips, house pads, and parking areas that were located inside of mapped wetland boundaries.

Polygons surrounding the fill were created heads-up (clicking with a mouse while viewing a screen), typically at a scale of 1:2000 or greater (zoomed-in). Digitizing heads-up is more time-consuming than automated techniques using LiDAR and the color signatures on aerial imagery, but it allows intervening human judgement. The boundaries of these fill polygons were digitized separately from the boundaries of the wetland polygons; i.e. the fill boundaries were not snapped to the boundaries of existing wetland polygons. Surface water surrounding the fill was usually visible on aerial photos, and the LiDAR showed the fill boundaries clearly, which often exceeded the mapped wetland boundaries. In many instances, small areas of wetland fill lying completely outside of mapped wetland polygons could be observed on the 2.5-foot resolution 2012 and 2013 fixed-wing imagery and LiDAR. These areas were also digitized heads-up. The area within the boundaries of the City of Homer was mapped at a scale of 1:12,000, and originally included wetlands that had been completely filled. In the final map product for the City of Homer the wetlands that had been filled prior to the passage of the Clean Water Act of 1972, which regulates placement of fill in wetlands, were omitted. Those formerly omitted wetland polygons were included to guide mapping of fill in this project.

The wetland area that the fill covered was digitized regardless of the extent of the wetland mapping. Because the mapping of the fill extent was performed at a different scale (1:12,000 or less), and with higher-resolution digital imagery than the wetland mapping (which was completed at a scale of 1:24,000, except the area within the Homer City Limits, which was mapped at a nominal scale of 1:12,000), a mismatch in boundary locations between the fill and the wetlands should be expected.

At a different level, wetlands had not been mapped in large portions two HUCs: Soldotna Creek and Longmere Lake. However, these unmapped areas were still examined for wetland fill, and fills were mapped there when discovered. The high resolution of the LiDAR and aerial photography along with the light development footprint within the unmapped areas both support confidence that the assessment of the actual extent of wetland fill there was accurate in the absence of the wetland mapping. The wetland mapping was performed prior to the availability of both of these high-resolution datasets.

In other instances, the extent of the original wetland was difficult to determine because the boundary between wetland and upland was obscured by the fill material. In these instances, the older imagery was used to guide the mapping of the boundary of the historic wetland. Moreover, to be certain that all filled wetlands were identified, all of the older imagery was examined at a scale of 1:4000. In a few cases, the older imagery revealed an historic wetland that had been completely obscured by fill. In other instances, the fill was sufficiently recent that the slightly older LiDAR hillshade (2008) helped guide the mapping of the boundary of the original wetland.

Analysis

The acres of wetlands filled was quantified by the type of wetland. A single fill polygon might cross several different geomorphic types of wetlands. Therefore, the wetland fill polygons were intersected with the wetland mapping polygons in ArcMap GIS so that the fill polygons could be classified by wetland type. These smaller polygons were further clipped to the boundaries of the 12-digit HUCs. The intersected and clipped wetland polygons were used to quantify wetland fill by HUC and by wetland type within the HUCs. The wetland types used for the analysis were the geomorphic components of the Cook Inlet Classification. This classification system was used in the wetland mapping and has been found to group wetlands that are more similar in important physical, biological, and chemical characteristics than other widely used classification systems (Gracz & Glaser 2016).

Field Verification

Eighty-one wetland fill polygons were visited to verify both the extent of fill and the nature of the wetland. In the southern HUC, wetland boundaries frequently occur along the gentle gradients of broad toe-slopes, while in the north, steeper gradients are generally present on the glacial landforms there. The visits were therefore concentrated in the Diamond Creek - Cook Inlet Frontal HUC, because wetland character along the gentle gradients is more difficult to discern from remote sensing. While using the remote sensing resources, if the wetland status was difficult to determine, fill was delineated, and the polygon marked for field visit. Therefore, the remote mapping relied on field verification to correct the presumed overestimate of the area of wetland fill that was mapped in difficult to determine areas.

Field sheets printed at a scale of 1:12,000 showing LiDAR and modern imagery along with wetland and numbered wetland fill polygons were taken to sites to assist editing of fill boundaries where required. A digital version of the same mapping used for the field sheets was also deployed in GPS software (LocusMap Pro) on a mobile phone (Samsung Galaxy s10e) to guide navigation. Wetland evidence and polygon boundary changes, if any, were recorded in a field notebook by referencing the numbered fill polygons on the field sheets and digital version.

RESULTS

A total of 50 wetland fill polygons were field-checked in the Diamond Creek - Cook Inlet Frontal HUC; and 31 were checked in the five HUCs encompassing Kenai, Soldotna, and Nikiski. The field visits in the Diamond Creek - Cook Inlet Frontal HUC resulted in 12 polygons being deleted because they were not wetlands. Nine others had their boundaries shifted. In the northern HUCs, where remote determination of wetland status is generally more straightforward, seven fill polygons were deleted following field visits and four had their boundaries modified to reflect conditions on the ground.

A total of 652 wetland fills covering 1631 acres remained mapped in the 47,364 acres of wetlands in the six HUCs (Figure 2). This acreage of filled wetlands is 3.44% of the total wetland acreage in the six HUCs. Although less than 5% of wetlands in the HUCs have been filled, the wetlands that have been filled are not uniformly distributed by location or by geomorphic type. Some HUCS have had few wetlands filled, while some types of wetlands have been filled to a greater extent within some HUCs. The geomorphic types described in the Cook Inlet Classification (Gracz & Glaser 2016) were used along with 12-digit Hydrologic Units to analyze the variability of wetlands that have been filled by type and location.

The percentage area of the wetlands filled in the HUCs encompassing Nikiski, Kenai, and Soldotna was less than the percentage area of wetlands filled in the HUC encompassing Homer (2.35 % vs. 6.64%). Within the northern five HUCs, two of them, Island Lake and Soldotna Creek, had less than 1% of their wetlands filled by area. Longmere Lake had less than 2% of its wetlands filled by area. Salamatof Creek had 2.3% of its wetlands filled by area and Sports Lake had 3.6% filled. In the south, more than 5% of wetland area was filled in the Diamond Creek - Cook Inlet Frontal HUC near Homer (6.64%). Although overall the wetlands in the south were more affected by fill, in both the southern and northern HUCs nearly a third of all wetland polygons mapped by type had at least some fill placed in them (31.2%). In the northern five HUCs, 614 of 1969 wetland polygons mapped by type contained some amount of fill. In the southern HUC, 706 of 2261 wetland polygons mapped by type were affected by fill. (Figure 3).

Within the six HUCs, more than five percent of the area of six types of wetlands has been filled (Figure 4). More than 6% of Lakebed wetlands in the Sports Lake HUC around Kenai and Soldotna have been filled (Figure 4**d**). Almost 20% of the Discharge Slope wetlands in the Salamatof Creek HUC, near Nikiski, have been filled, and nearly 5% of Riverine wetlands there have also been filled (Figure 4**e**). Nearly 5% of the area of Kettles around Homer, in the Diamond Creek - Cook Inlet Frontal HUC have been filled, along with nearly 15% of Discharge Slope area and over 20% of the area of Depressions. Some of these percentages mark relatively small absolute areas of filled wetlands, for example 5% of Riverine wetlands in the Salamatof Creek HUC is only 1.3 acres of the relatively scarce Riverine wetlands in that HUC. However, one of the largest percentage of wetlands filled, 15.2% of Discharge Slopes in the Diamond Creek - Cook Inlet Frontal HUC around Homer translates into almost 550 acres of wetland fill there. See Appendix A for a complete tabulation of percent and area of wetland fills by type in each HUC.

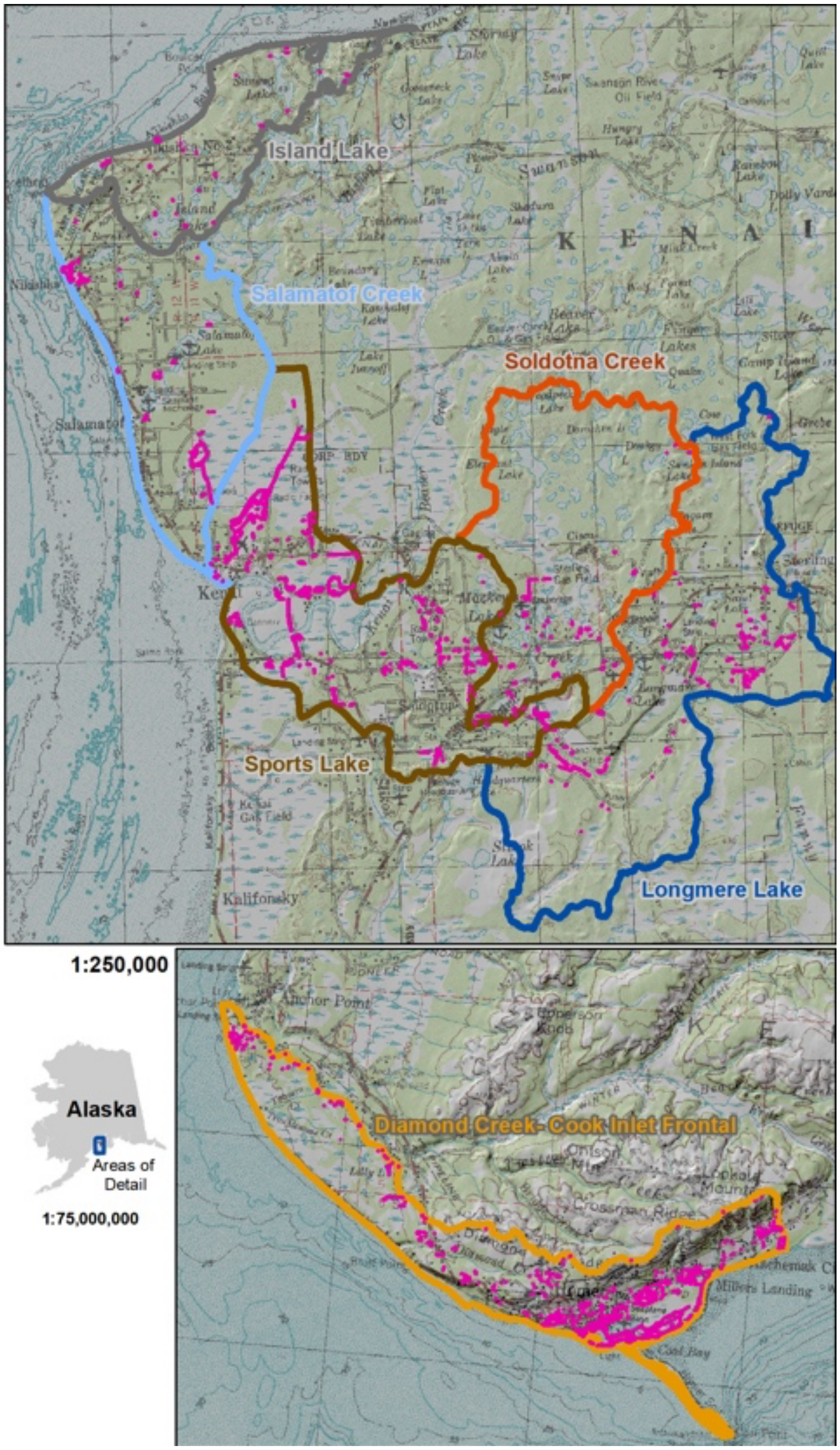

Figure 2. Wetland fill (pink) in the six HUCs (labeled). The wide pink borders of the filled wetland polygons exaggerate their area.

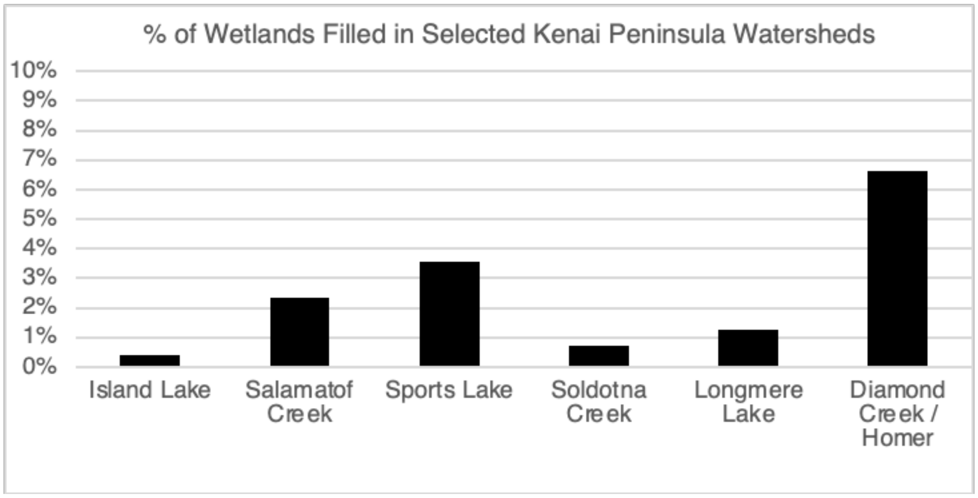

Figure 3. Percentage area of filled wetlands within each of the six HUCs investigated.

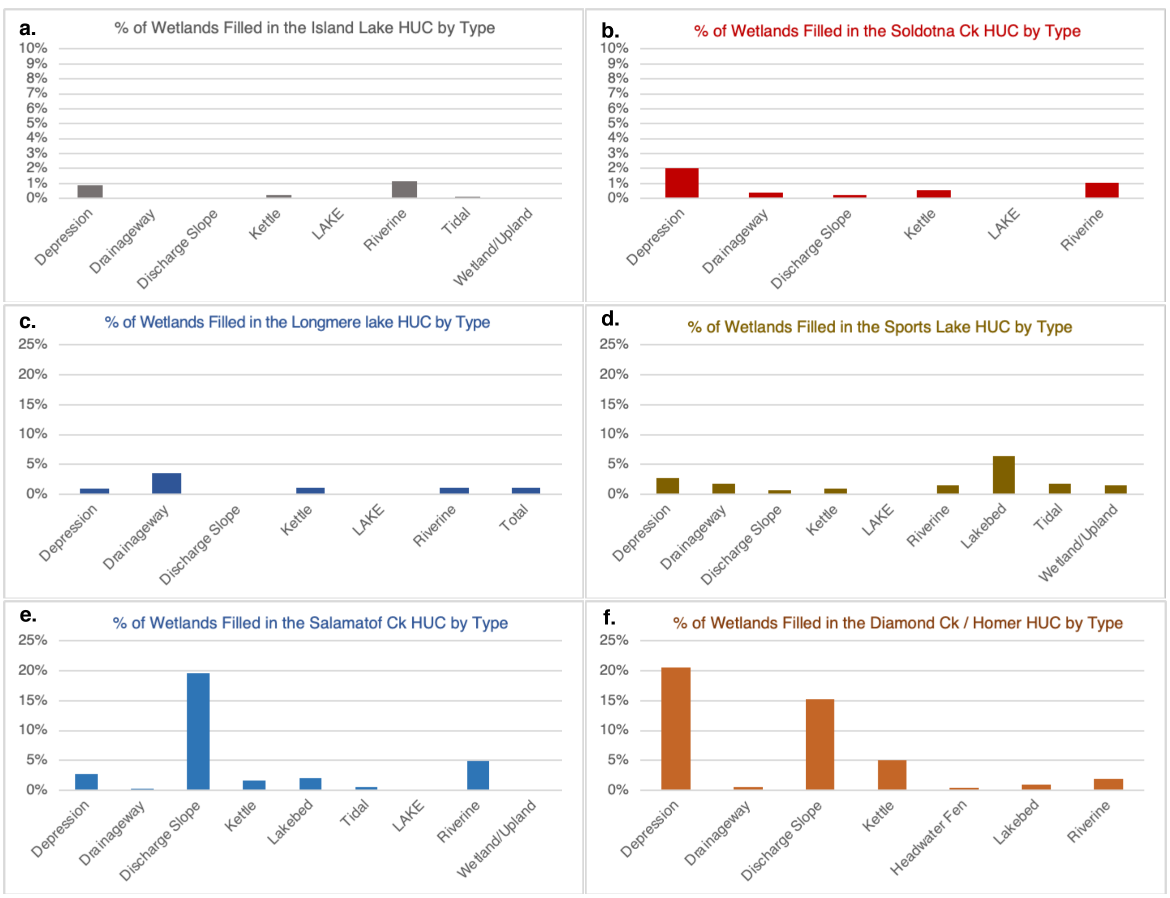

Figure 4 **a. - f**. Percentage of wetlands filled by type within each of the six HUCs (**a. - e.**). Notice the y-axis scale difference between Figure 3 and 4**a.** & **b.** and 4**c.**-**f.** Wetland types with no fill were omitted.

DISCUSSION

Field verification of a comparison of early 1950's aerial photography to modern 2.5-foot resolution aerial photography that was acquired in 2012-2013 identified 652 separate wetland fills covering 1631 acres of six HUCs encompassing the population centers of the western Kenai Peninsula Borough. Although overall the wetlands in the south were more affected by fill (6.64% by area vs. 2.35%), in both the southern and northern HUCs nearly a third of all wetland polygons mapped by type had at least some fill placed in them (31.2%). In the northern five HUCs, 614 of 1969 wetland polygons mapped by type contained some amount of fill. In the southern HUC, 706 of 2261 wetland polygons mapped by type were affected by fill. Many individual wetland fills covered more than one wetland type.

Because the modern imagery was acquired eight or nine years ago (Homer, and Kenai-Soldotna respectively), the acres of wetland fill reported here can be assumed to be an underestimate. Probably little fill has been removed from wetlands in the intervening eight or nine years, and certainly more fill has been added. Mapping errors- mapping fill where none exists or omitting fill that does exist- are probably very small, due to the quality of the LiDAR and aerial imagery, the field verification effort, and the extensive experience of the investigator with mapping wetlands in the region.

Although the total area of wetland fill represents only a little more than 3 percent of the overall area of wetlands within the six HUCs, some wetland types have been filled within some HUCs at a disproportionately higher rate. In the Diamond Creek - Cook Inlet Frontal HUC encompassing Homer, 6.64% of all wetlands have been filled. More than ten percent of three geomorphic types of wetlands have been filled in two different HUCs. In the most extreme case, 547 of the 3600 acres of Discharge Slope wetlands within the Diamond Creek - Cook Inlet Frontal HUC have been filled (15.2%). In that same HUC, which encompasses the area between the Anchor River and Fritz Creek, 25 of the 121.5 acres of Depression wetlands have also been filled (20.6%).

Generally, the estimation of wetland loss by comparing modern and historical aerial imagery has limitations. Wetland fills are typically well-established by the time of the earliest imagery, and the interpretation of wetlands on the historical imagery is impossible to verify in the field today. Even with modern, high-resolution imagery, interpretation of wetland extent without field verification can lead to over- or under-mapping of wetland fill polygons.

In the six HUCs of the Kenai Peninsula Borough that were examined here, those limitations are minimized because aerial imagery is available from a time when the footprint of wetland fill was almost completely absent. Moreover, the author has extensive experience mapping wetlands in the project area, including extensive field verification, which minimizes errors of interpretation on the modern imagery. However, the boundaries of the fill polygons are inexact, and a fine-grained, site-specific analysis of any individual fill polygon would certainly lead to a different calculation of the total area of wetlands that have been filled. However, these limitations are expected to be minor for the purposes of a general assessment of watershed-wide cumulative impacts.

Reporting losses as percentages can be misleading when the absolute acreage is small (e.g. a loss of a half-an-acre of a wetland for a type that only covers a total of one acre is a 50% loss of wetlands over a small total area). However, many of the wetland types with substantial amounts of fill also cover relatively large areas. For example, Kettles, Discharge Slopes, and Tidal wetlands in the Diamond Creek - Cook Inlet Frontal HUC; Drainageways in the Longmere Lake HUC; Lakebeds in the Sports Lake HUC, Depressions and Lakebeds in the Salamatof Creek HUC; and Depressions in the Soldotna Creek HUC all have more than 2% of their wetlands filled and also cover more than 250 acres.

Filling wetlands compromises their function, which decreases their value to society as green infrastructure. The percentage of wetlands that can be filled before functions are substantially compromised is unknown. However, it has been widely reported that stream quality decreases rapidly once impervious cover in a watershed reaches ten percent (Schueler 1994; Booth & Jackson 1997; Schueler et al. 2009; Loperfido et al. 2014). In Alaska, this decrease in stream quality may be seen with impervious cover values lower than five percent (Ourso and Franzel 2000). It can be assumed that wetlands are covered by impervious surfaces (i.e. filled) at a lower rate than uplands because building is less desirable and more expensive on wetlands. Therefore, if more than ten percent of wetlands are filled within a HUC, it may be reasonable to assume that an even larger percentage of the surrounding uplands are covered by impervious cover. If this assumption is true, and if the quality of streams is more sensitive to impervious cover in the boreal climate of Alaska, then filling of more than five percent of wetlands in a boreal HUC probably will cause substantial declines in at least some streams. More work is required to test these two key assumptions.

Management Recommendations

It is prudent to assume that wetland losses of more than five percent by area in boreal watersheds will cause declines in stream quality. More than five percent of the wetland area has been filled in the Diamond Creek – Cook Inlet Frontal HUC. More than ten percent of the area of three types of wetlands in two HUCs have been filled. More than five percent of five types in three of the HUCs have been filled. These different types of wetlands have different functions that are valued by society as green infrastructure. Therefore, additional filling should cease, or compensatory mitigation should be required if unavoidable impacts are to be permitted in any of the following types of wetlands in these HUCs, which all have more than 5% of their area filled:

- Sports Lake
  - Lakebed wetlands
- Salamatof Creek
  - Discharge Slopes, and Riverine wetlands
- Diamond Creek-Frontal Cook Inlet
  - Depressions, Discharge Slopes, and Kettles

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APPENDIX A

Wetland losses by type and HUC in units of acres and percentages.

HUC	Wetland Type	Wetland acres	Filled acres	% Wetland area filled
Diamond Creek – Cook Inlet Frontal	Depression	121.5	25	20.58%
	Drainageway	357.7	2.2	0.62%
	Discharge Slope	3599.9	547.3	15.20%
	Kettle	2046.5	104	5.08%
	Headwater Fen	34.5	0.16	0.46%
	Lakebed	3448.2	32.1	0.93%
	Riverine	965.6	18.5	1.92%
	Wetland / Upland	1149.1	53.2	4.63%
	Tidal	254.4	9.7	3.81%
	Total	12040.5	799.46	6.64%
Longmere Lake	Depression	621.3	5.8	0.93%
	Drainageway	401.7	14.1	3.51%
	Discharge Slope	82.8	0	0.00%
	Kettle	1457.9	15.5	1.06%
	LAKE	501.9	0.0004	0.00%
	Riverine	1089.0	12	1.10%
	Total	4154.6	47.4	1.14%
Soldotna Creek	Depression	682.4	13.8	2.02%
	Drainageway	1566.6	6	0.38%
	Discharge Slope	415.8	1	0.24%
	Kettle	1410.7	7.7	0.55%
	LAKE	1322.4	0.2	0.02%
	Riverine	473.0	5	1.06%
	Total	5870.9	33.7	0.57%
Salamatof Creek	Depression	514.3	14.3	2.78%
	Drainageway	308.0	1.1	0.36%
	Discharge Slope	222.3	43.7	19.66%
	Kettle	454.2	7.7	1.70%
	Lakebed	2134.9	43.1	2.02%
	Tidal	168.4	0.91	0.54%
	LAKE	699.3	0.14	0.02%
	Riverine	26.3	1.3	4.94%
	Wetland/Upland	292.3	0.02	0.01%
	Total	4820.0	112.3	2.33%
	Depression	927.1	8.4	0.91%
Island Lake	Drainageway	99.3	0.04	0.04%
	Discharge Slope	3.0	0	0.00%
	Kettle	576.9	1.44	0.25%
	LAKE	1110.0	0.38	0.03%
	Riverine	45.3	0.52	1.15%
	Tidal	148.9	0.15	0.10%
	Wetland/Upland	382.5	0.00016	0.00%
	Total	3293.0	10.9	0.33%