Technical Report

LOWER COLUMBIA RIVER MORPHOLOGY AND FISH STRANDING

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Technical Report
Lower Columbia River Morphology and Fish Stranding

1. Introduction

Physical conditions along the banks of the Columbia River (as well as vessel wake characteristics) determine hydrodynamics of vessel wake propagation close to the banks and its dissipation over the bottom slope, and in turn affect the potential for stranding juvenile fish. These physical conditions include but are not limited to river bank geomorphology (three-dimensional geometric shape and composition of sediment), river hydraulics (flow elevations and velocities), passing vessel particulars and navigation conditions (such as vessel dimensions, speed relative to river flow[1], relative bearing and distance from shoreline), among others. Varying geomorphic, hydraulic and hydrodynamic, and vessel hydrodynamic conditions along river banks result in variable rates of stranding. The ability of vessel wakes to strand fish was demonstrated by previous studies, including a field study by Pearson *et al.* (2006). Pearson *et al.* (2006) observed significant differences in fish stranding rates by vessel wakes at three sites along the Lower Columbia River (LCR): Barlow Point (stranding hot spot) vs. Sauvie Island and County Line Park (small rate of stranding).

The purpose of the current study was to:

- Evaluate site-specific geomorphologic conditions at the three (LCR) sites studied by Pearson *et al*. (2006): Barlow Point, Sauvie Island, and County Line Park.
- Interpret the differences in stranding risk at these three sites based on the differences in geomorphology and other physical factors.

2. LCR Sites Morphology

2.1. Barlow Point

The morphology at Barlow Point was investigated based on available aerial and ground photographs, and previous bathymetric survey data. Figure 1 is a 2012 aerial photograph (source: Google Earth) of the Barlow Point area with the boundaries of the site as specified by a previous study (Ackerman 2002).

[1] Please note the importance of vessel speed relative to river and tidal flow as opposed to ground speed. The former speed plays a significant role in creating vessel wakes and pressure fields; whereas, the latter speed is not the right factor to be accounted for depending on the river/tidal flow direction and speed.

Figure 1. Barlow Point aerial photo with site boundaries specified by Ackerman (2002)

The aerial photograph indicates the complexity of the shoreline in this area and shows that the river bank is composed of several different morphologic features. A wide, flat upper beach exists at the downstream side of the Barlow Point site. This beach is also shown in Figure 2 that presents three ground photographs of the site. The wide beach is bordered on the upstream side by a headland-like feature that divides the site into two distinct parts. This "headland" can be seen in Figures 2(a) and 2(c). Further upstream, past the headland, the upper beach is less visible in the photos and it seems that the backshore of the river bank in this upstream stretch is armored with rock and rubble (See Figures 2c and 2d). The armoring of the backshore indicates the width of the upper beach is insufficient to attenuate the energy of waves or vessel wakes prior to contact with an otherwise erodible shore.

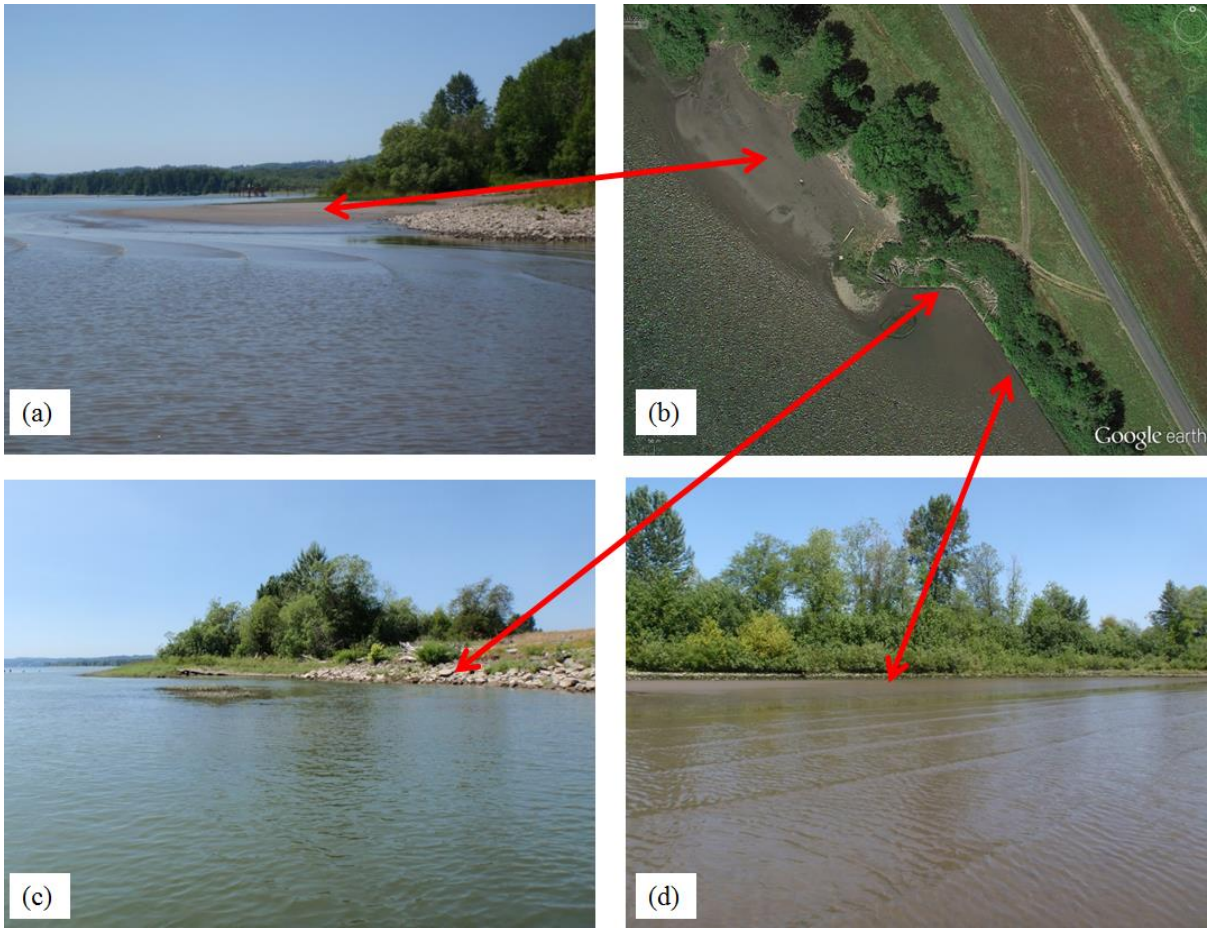

Figure 2. Barlow Point ground photographs (a), (c), and (d) demonstrate the various features of the site, shown in relation to the aerial photograph (b)

An attempt was made to identify the locations of the samples of stranded fish recorded by the Pearson *et al.* (2006) study, and relate these locations to the morphologic conditions at Barlow Point. For this purpose, the map of recorded stranding locations (Figure 25 from the Pearson *et al*. (2006) study) was superimposed onto a Google Earth aerial photograph[2] (see Figure 3).

[2] Please note that Pearson *et al*. (2006) did not provide locations of fish stranding in a referenced coordinate system. Additional analysis was conducted to accurately (as best as possible) layout the map from the previous study on a geo-referenced Google Earth aerial photograph.

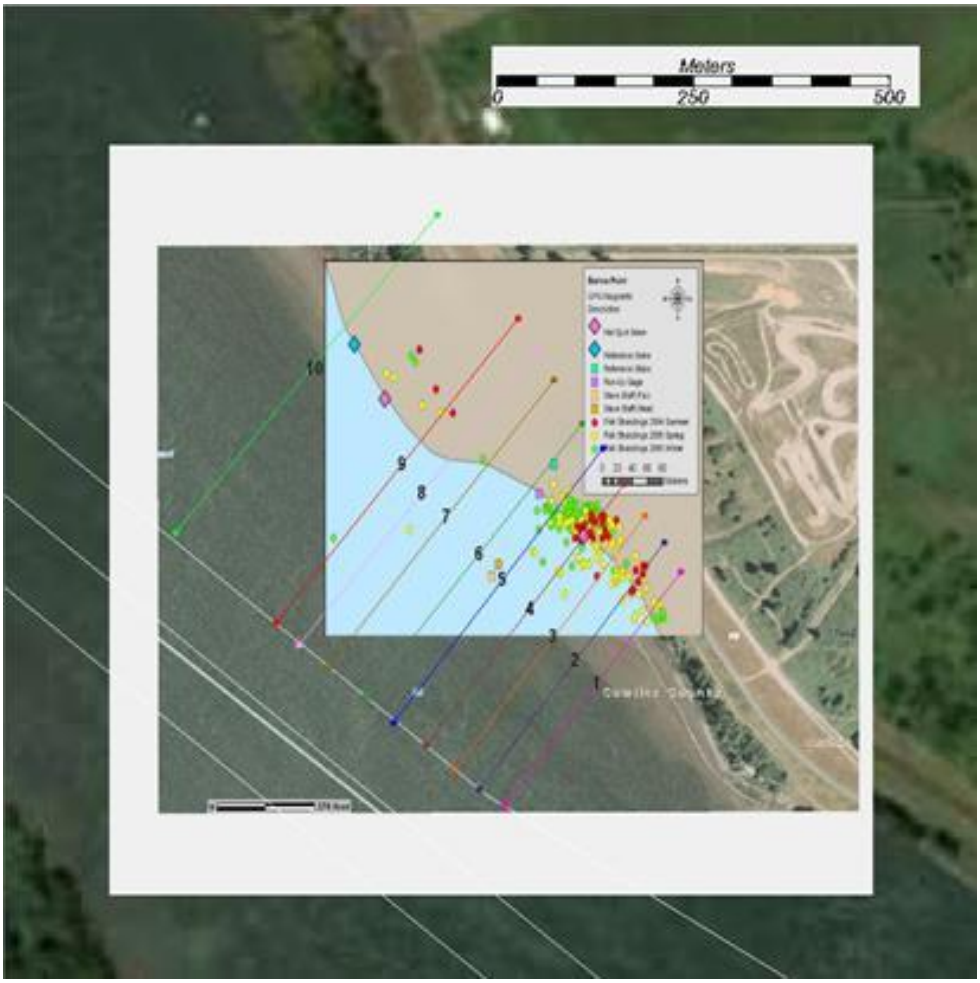

Figure 3. Barlow Point stranding locations, from Pearson *et al.* (2006) study (Figure 25) superimposed to aerial photograph

Figure 3 shows very little stranding was observed at the downstream stretch of the Barlow Point site that is represented by a wide and extensive upper beachface. In fact, most of the stranding occurred in the upstream stretch of the site with a less distinct upper beach and an armored backshore. It appears that a combination of local morphologic conditions with hydraulic and hydrodynamic characteristics is likely to have generated a stranding hot spot at a specific stretch of the Barlow Point site.

It is notable that the same observation (though not explicitly mentioned in the report) was obtained from a previous study conducted by Ackerman (2002)[3]. Figure 4 shows two photographs taken at Barlow Point of the stranding hot spot.

[3] The data (Table 6 of Ackerman 2002 report) shows that the amount of stranded fish in the upstream reach of Barlow Point is approximately 8 times higher than that stranded fish at the downstream reach.

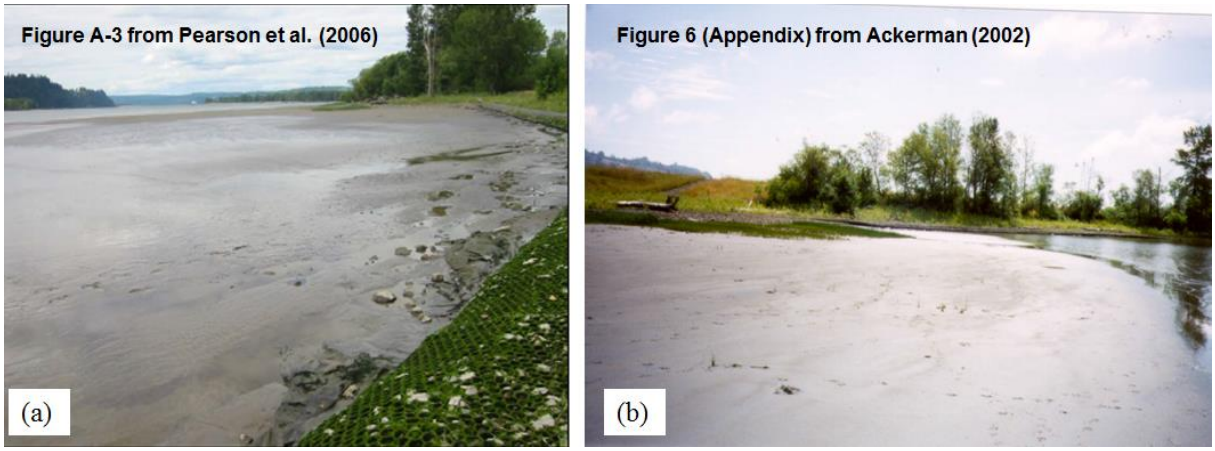

Figure 4. View of Barlow Point site where most fish strandings occurred: (a) Figure A-3 from Pearson *et al.* (2006); and (b) Figure 6 from Ackerman (2002)

Figure 4 shows photographs of the Barlow Point site where a stranding hot spot was observed during the previous studies. The pictures were most likely taken at low river flow and show an extensive lower beach, with armor scattered at the backshore[4].

To identify the specific morphologic conditions that are related to higer occurrence of fish stranding, a more detailed analysis of beach morphology and beachface slope at Barlow Point was conducted using the available hydrographic and topographic survey data. Figure 5 shows the bathymetry at Barlow Point in color format with the boundaries of the Federal Navigation Channel as white lines.

Figure 5 shows the complexity of the river and navigation channel alignment that makes a turn close to Barlow Point, forming a concave shape of shoreline. One should expect specific hydrodynamic effects along this stretch of riverbank from all types of passing vessels and boats (including fishing and pleasure). The effect of a concave shaped shoreline on vessel wake transformation has not been sufficiently investigated yet, but existing data demonstrate that this shape of shoreline may result in amplification of wave parameters. It is likely that the stranding hot spot, an upstream stretch of Barlow Point, located on a concave shoreline at close proximity to the turning point, is subjected to these unique effects more substantially.

The upstream areas of the site (encompassed by Transects 1-5, see Figure 3) is represented by a flat underwater terrace with a width of approximately 300 ft. At this portion of the site, there is none (or minimal) upper beach, and rock armoring is present at the landward side. A more detailed investigation of slope configuration was conducted using cross-sectional transects. Figure 5 shows the locations of transects that were used for analysis of bathymetric data. The data were extracted along each of these transects and compared. Figure 6 shows an example of comparison at two representative transects; Transect 1 and Transect 9.

[4] It is likely that during other tide elevations most of the area of lower beach, shown in Figure 4(a), is covered with water.

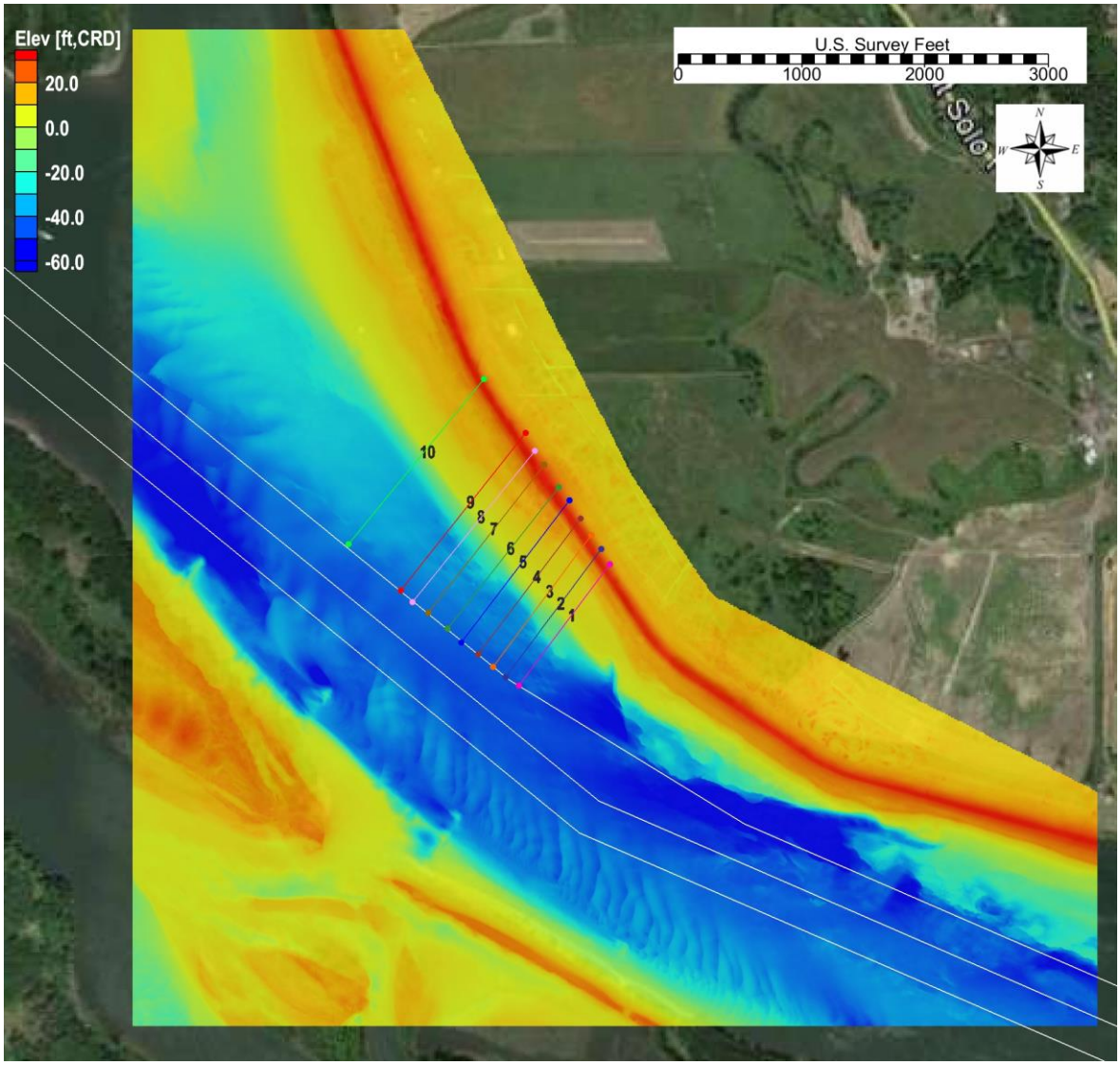

Figure 5. Bathymetry and topography data at Barlow Point site vicinity

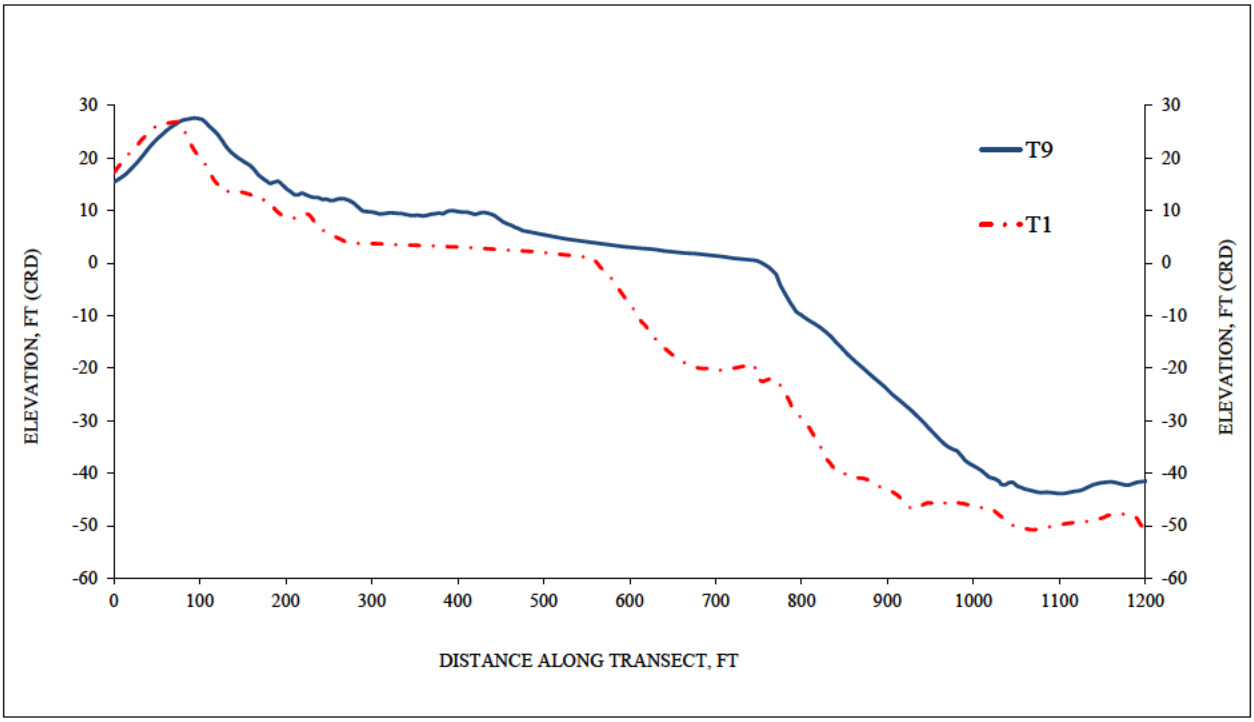

Figure 6. Barlow Point, example comparison at two representative Transects 1 and 9

The figure shows a relatively steep offshore slope facing the deep water of the navigation channel at both transects. However, at Transect 9, toward the shoreline, a steep slope transforms into a gradual and flat slope at water depth close or below 0.0 ft CRD. A flat slope on this transect extends landward and forms a wide upper beach. This type of slope configuration, a wide, gradual beach, extending deep below normal water level is typical for the downstream section of Barlow Point. As previously discussed, the downstream part of Barlow Point is located further from the turning point of the river and likely is less affected by unique hydrodynamic conditions of the river flow and passing vessels and boats. It is also likely that a wide upper beach, extending deep below water level has strong dissipative capacity for attenuation of all types of wakes, specifically generated by deep-draft vessels. Interaction of vessel wakes with this type of beach slope causes an effective transformation of kinetic energy of water motion (wake surge) into potential energy (increased water elevation). It is appropriate to assume that the upland-directed hydrodynamic force from the vessel wake arriving at the upper part of shoreline is reduced and not sufficient to generate a fish stranding effect; thus, the fish stranding effect at this type of shoreline is minimal.

Along Transect 1, toward the shoreline, a steep slope transforms into a flat, barely horizontal slope representing a wide underwater[5] terrace with a narrow, or no beach. This type of slope configuration, mostly horizontal with a wide, underwater terrace and a narrow, or no upper beach, is typical for the upstream section of the Barlow Point shoreline. First, as discussed above, the upstream part of Barlow Point is located close to the turning point of the river and likely is affected by unique

[5] For most of tide conditions

hydrodynamics conditions of the river flow and all passing boats (shallow draft and deep draft). Secondly, but not lastly, it appears the wide underwater terrace does not have strong dissipative capacity for attenuation of vessel wakes. Vessel wakes with this type of beach slope propagate a long distance with small dissipation. The residual wake energy breaks on the upper part of the riverbank. This explains the need for shoreline protection at this area.

The locations of the sites relative to the turning point and two patterns of vessel wake energy dissipation described at two areas of Barlow Point are consistent with the fish stranding results obtained from the previous studies. The highest level of fish stranding was observed at the upstream part of the Barlow Point shoreline (close to the river bend and low capacity for vessel wake dissipation). The lower level of fish stranding was observed at the downstream of the Barlow Pt. shoreline, (more remote location of river band and high capacity for dissipation of vessel wake due to wide, gradual beach)

2.2. County Line Park Morphology

The morphology at the County Line Park area was investigated based on available aerial and ground photographs, and previous bathymetric survey data similar to Barlow Point. Figure 7 is an aerial photograph (from Google Earth) of the County Line Park area, with the boundaries of the site, as specified by Ackerman (2002).

The aerial photograph indicates a relatively uniform (no obvious turning bend) shoreline configuration, with small variability at the upstream boundary. A small and well-defined upper beach is visible in most parts of the County Line Park area. The beach is shown in Figure 8, which presents three ground photographs of the site. A portion of the shoreline in the downstream area has a limited upper beach. In this area, the armored shoreline extends close to the lower beach; see Figure 8(c). However, even at this part of shoreline an upper beach is present.

Figure 7. County Line Park aerial photo with site boundaries

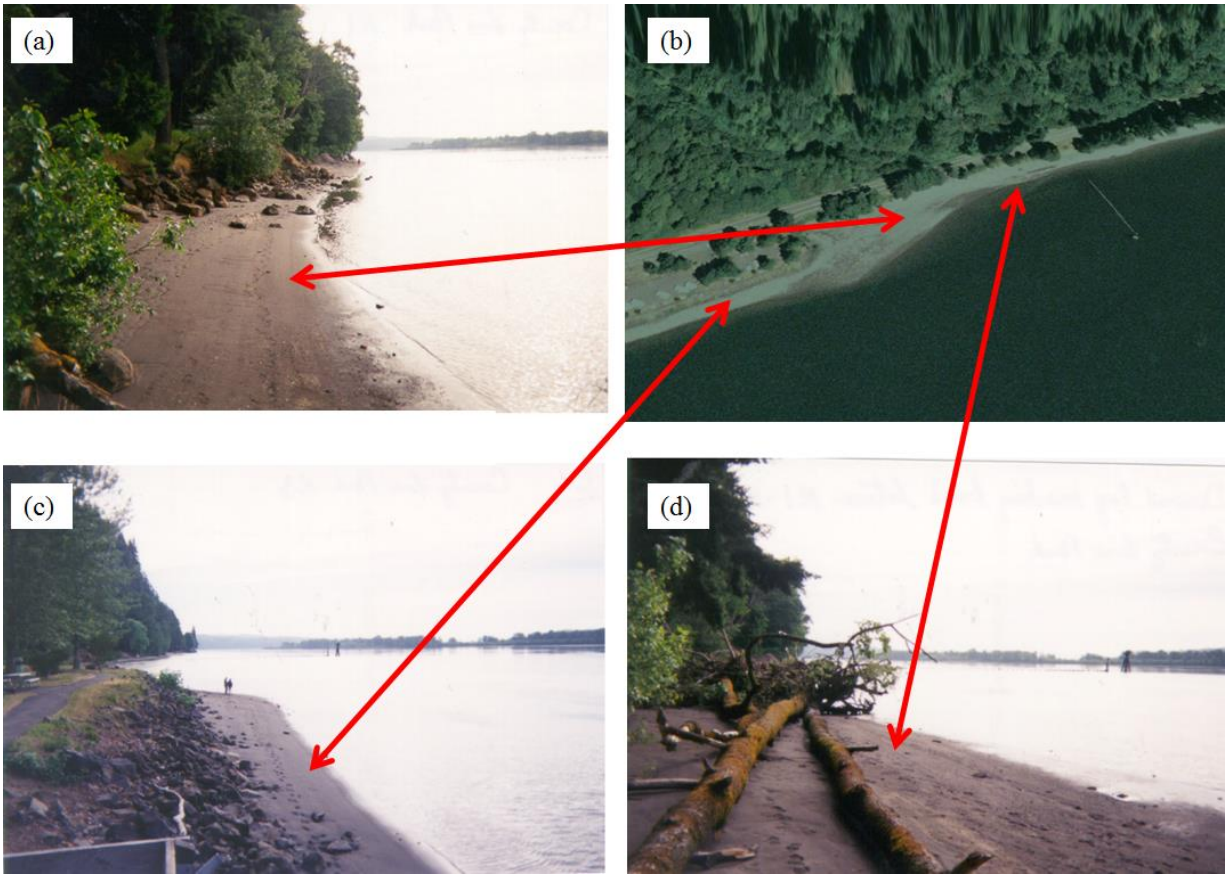

Figure 8. County Line Park ground photographs from Ackerman (2002): (a), (c) and (d) shown in relation to an oblique aerial photograph: (b)

Figure 9 is from the Pearson *et al.* (2006) study (Figure 26) and shows stranding locations at the County Line Park site. The figure shows a relatively low density of stranding observations along the shoreline at this site, compared to Barlow Point. To identify specific morphologic conditions and to correlate these morphologic conditions to the observed fish stranding, 3-D analysis of bottom slope configuration at the County Line Park site was conducted using available hydrographic survey data. Figure 10 shows the bathymetry at County Line Park in color format. The figure also shows the boundaries of the Federal Navigation Channel as white lines.

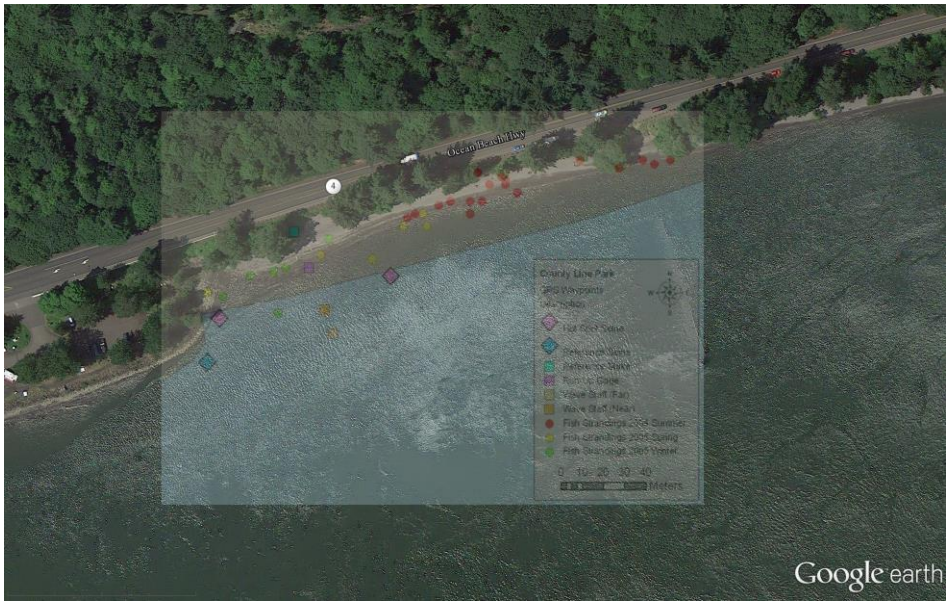

Figure 9. County Line Park Stranding Locations, from Pearson *et al.* (2006) study (Figure 26)

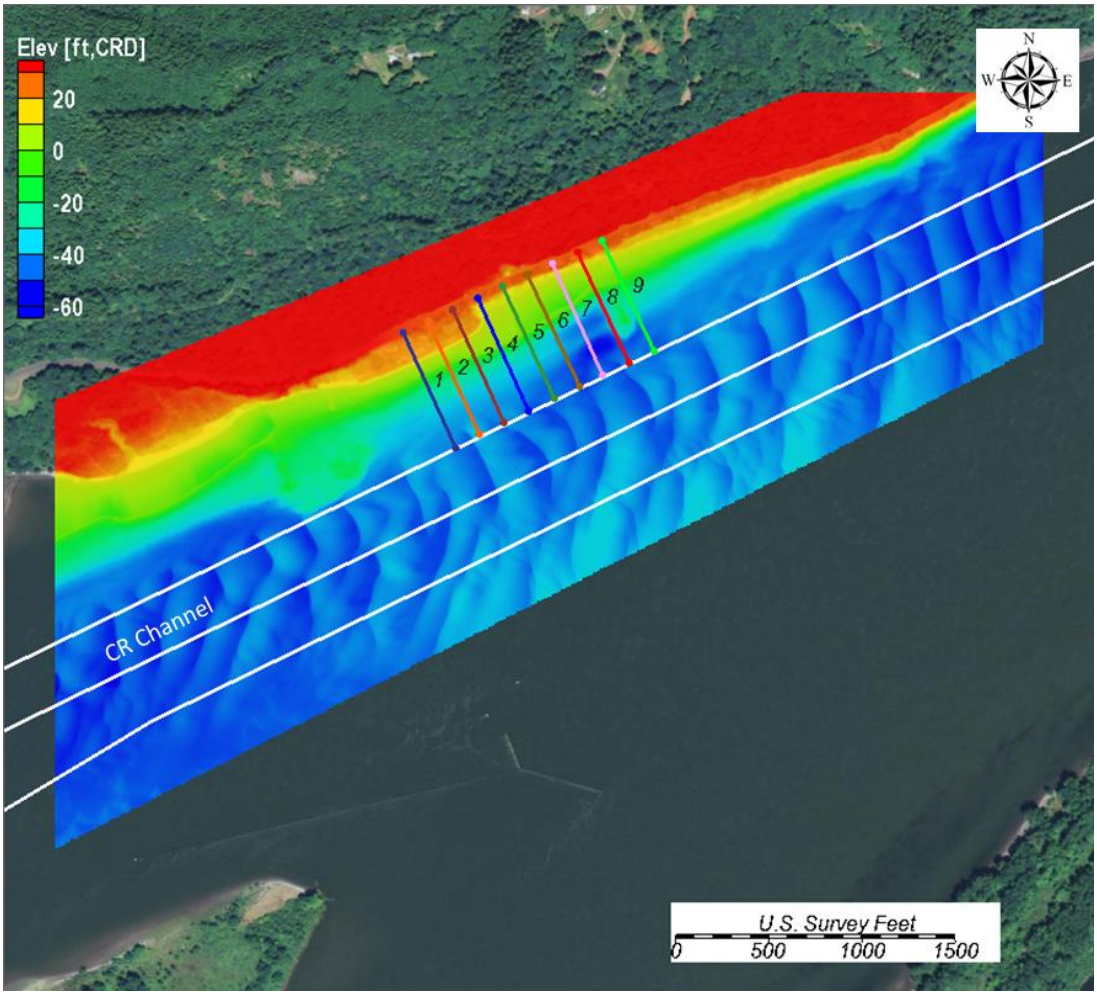

Figure 10. Bathymetry and topography data at County Line

Figure 11 shows relatively uniform slope configurations along the river bank at the County Line Park area. The upper beach is presented for most of the shoreline length.

A more detailed investigation of slope configuration was conducted using the cross-sectional transects. Figure 10 shows the locations of transects that were used to analyze bathymetry data. The bathymetry data were extracted along each of the transects and compared to each other. Figure 11 shows an example of comparing two transects: Transects 1 and 9.

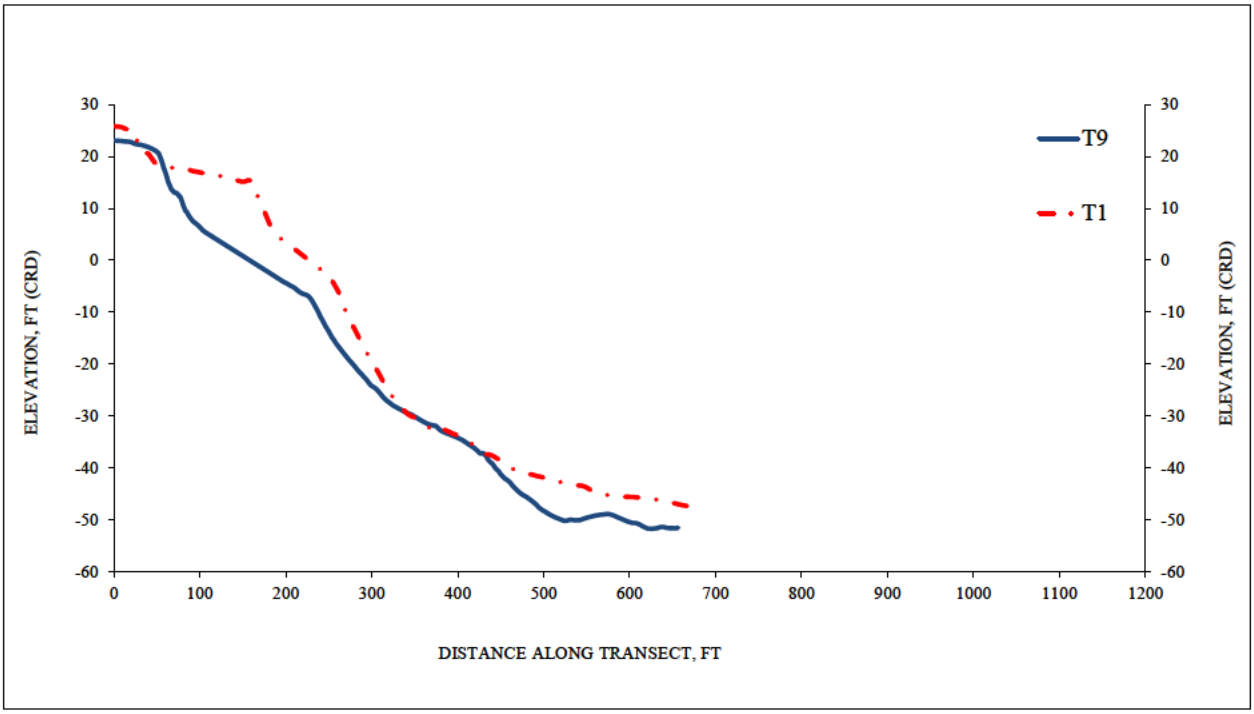

Figure 11. County Line Park, example comparison at two representative Transects 1 and 9

The figure shows a relatively uniformed (gradual) and steep slope, extending to the depth of 40 ft CRD and facing the deep water of the navigation channel. An average estimated steepness of this slope is 1V:6 H or less. A small and steep upper beach is present at both transects.

Apparently an interaction of vessel wakes and this wake transformation on the bottom slope starts at a deep part of the slope and gradually progresses toward the shoreline. As discussed above, a gradual process of transformation results in effective dissipation of wake energy. When a vessel wake arrives at the upper part of the beach, the upward-directed hydrodynamic force from this wake is reduced and apparently not sufficient to generate a significant fish stranding effect. In addition a steep slope trends to reflect the wave energy. Therefore, some energy of vessel wakes reflects from the slope at deep water and does not reach the shoreline at all. These two phenomena, gradual dissipation and probably wave reflection, explains the relatively small amount of fish stranding events observed at this part of site.

2.3. Sauvie Island Morphology

Similar to the previous two sites (County Line Park and Barlow Point), morphology at the Sauvie Island shoreline was also investigated based on available aerial and ground photographs, and previous bathymetric survey data. Figure 12 is an aerial photograph (from Google Earth) of the site with the boundaries of the site, as specified by the Ackerman (2002) study.

The aerial photograph indicates a relatively uniform shoreline with small variability at the upstream and downstream boundaries. An extensive beach is defined at most

parts of the County Line Park area. This beach is also shown in Figure 13 (a) which presents ground photographs of the site.

Figure 12. Sauvie Island shoreline aerial photo with site boundaries specified by Ackerman (2002)

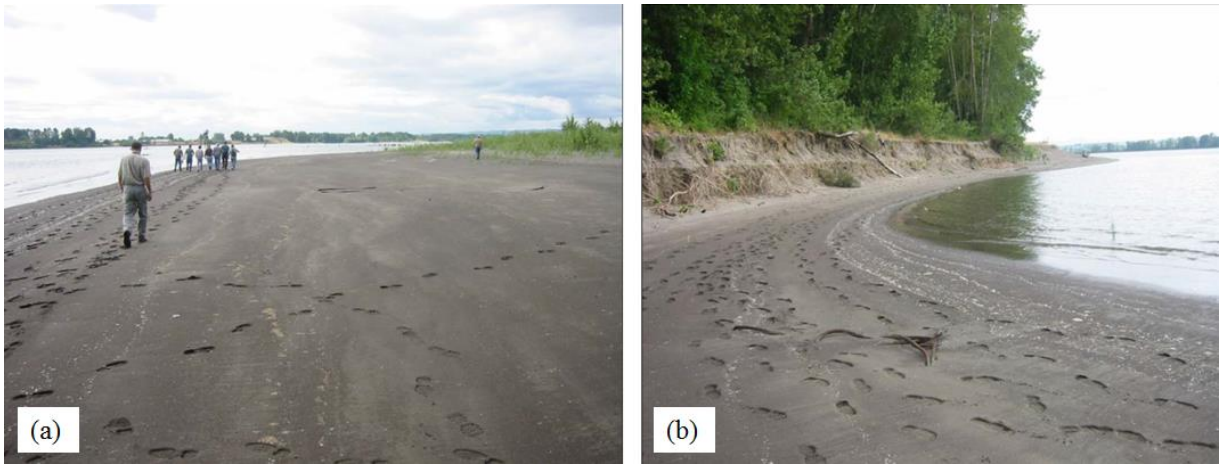

Figure 13. Sauvie Island ground photographs, from Pearson *et al.* (2006)

Figure 14 is from Pearson *et al.* (2006) (Figure 27) and shows the locations of samples of stranded fish at the Sauvie Island shoreline area.

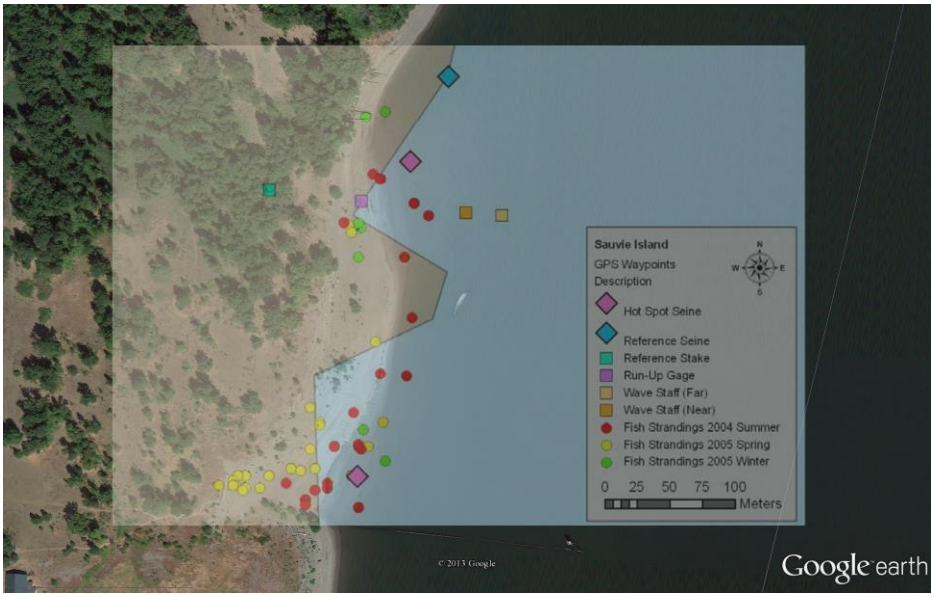

Figure 14. Sauvie Island Stranding Locations, from Pearson (2006) (Figure 27)

Figure 14 shows that stranding of fish had occurred relatively uniformly along most of the shoreline. The density of fish stranding increases toward the end of the upstream boundary of the site. However, this density increase is still small relative to Barlow Point. Figure 15 shows the bathymetry and topography data along the Sauvie Island riverbank in color format. The figure also shows the boundaries of the Federal Navigation Channel as white lines.

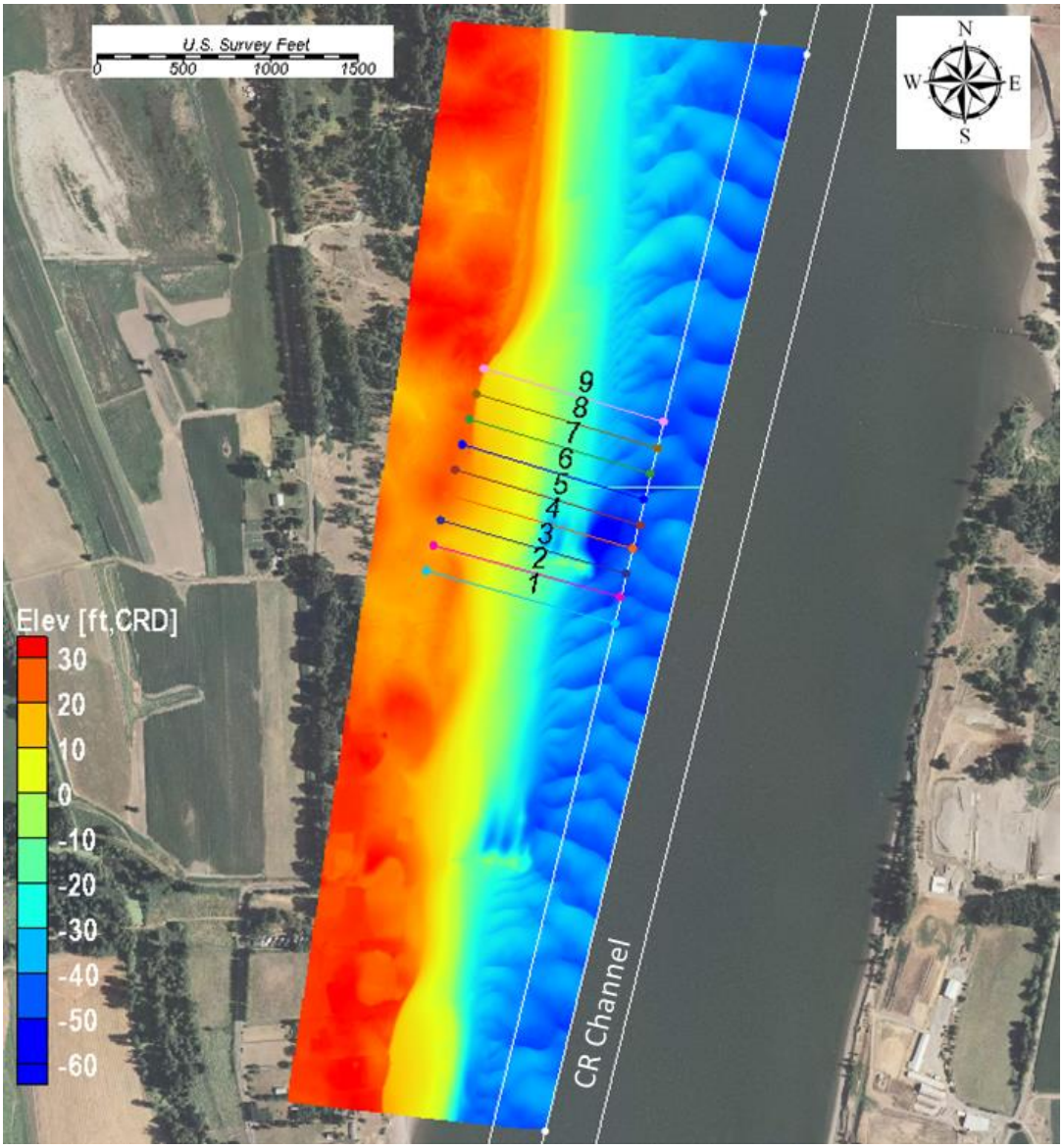

Figure 15. Bathymetry along river bank at Sauvie Island

Figures 14 and 15 show relatively uniform slope configurations along the riverbank at the Sauvie Island area. The wide beach is well developed and is present along most of the shoreline length. A more detailed investigation of slope configuration was conducted using the cross-sectional transects. Figure 15 shows the location of transects that were used to analyze the bathymetric data. The bathymetry data were extracted along each of the transects, superimposed, and compared to each other. Figure 16 shows an example comparison of two transects: Transects 1 and 9.

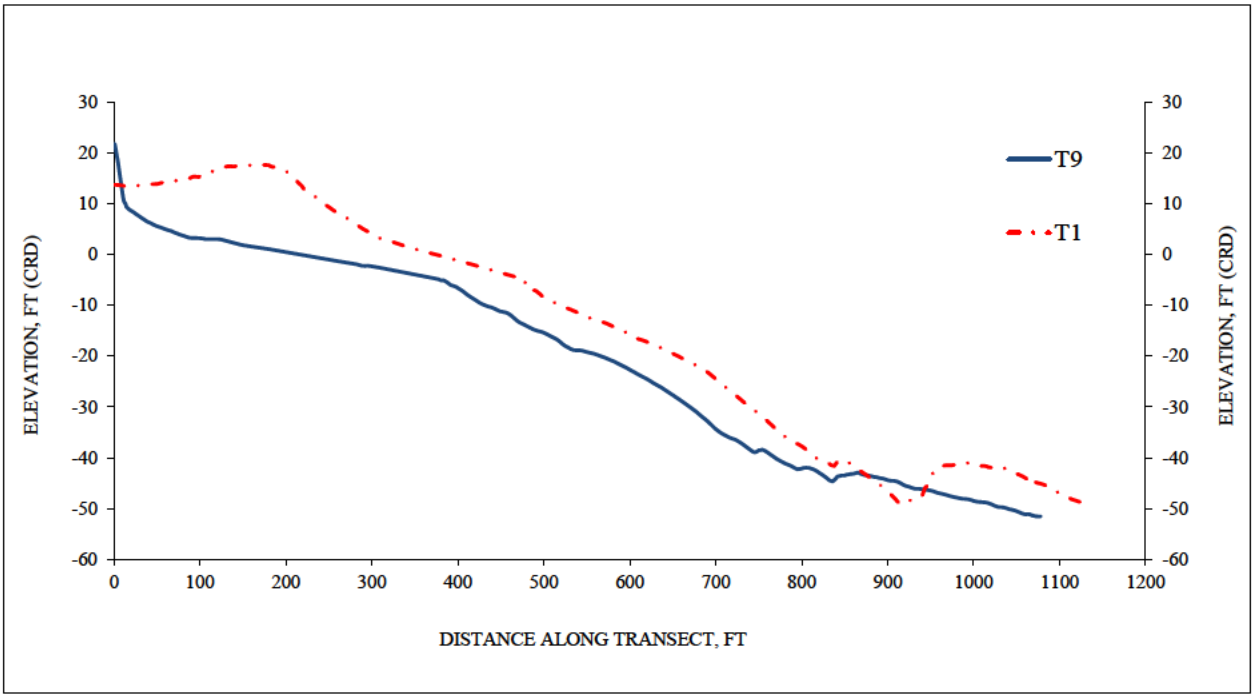

Figure 16. Sauvie Island, example comparison Transects 1 and 9

The cross-section in the figure is presented by a gradual slope extending from the deep water at the navigation channel toward the upper river bank with the averaged estimated slope at 1V:10H. It should be noted again that the slope is relatively uniform and indicates the presence of a wide beach. This type of morphologic configuration, a gradual slope with a wide beach, is typical for most of the shoreline. As discussed above, a gradual flat slope likely provides favorable conditions for dissipation of wave energy and attenuation of vessel wakes. Interaction of vessel wakes with this type of beach slope generates a high level of turbulence that causes an effective transformation of kinetic energy of water motion (wake surge) into potential energy (increases water elevation). This pattern of vessel wake energy dissipation is consistent with the fish stranding data collected at the Sauvie Island shoreline during previous studies. The level of fish stranding at this site is low compared to Barlow Point.

3. Summary

Analysis of available aerial and ground photographs as well as bathymetric and topographic data was conducted to determine site-specific morphologic conditions at three sites along the Lower Columbia River (LCR) studied by Pearson *et al*. (2006): Barlow Point, County Line Park, and Sauvie Island.

The analysis has preliminarily identified morphologic features that, in combination with particulars of vessels wakes, could potentially be used as an indicator of fish stranding potential. These features, if confirmed by additional studies, can be used further to distinguish the LCR shoreline in regard to fish stranding potential.

Based on the current study, the morphologic features that may potentially be used as an indicator of LCR shoreline stranding potential consist of turning points of the river (river bends), and configuration of the bank slope and upper beach at the shoreline.

It is known that unique hydrodynamic effects from river flow and all types of passing vessels (including shallow draft and deep draft) may occur in areas at close proximity to river bend. It is also known that these effects differentiate, depending on the type of river bend site; concave or convex. Passing vessels (all types of vessels) at river bend (most likely at concave sites) in combination with specifics of river flow and morphologic features may form unique hydrodynamic effects that result in the ability of stranding certain types of fish. Therefore, one indicator of potential fish stranding effect may be a river bend, specifically the concave side of the bend. Shoreline at close proximity to this bend may have a potential for stranding fish if other physical conditions and morphologic factors, such as bank slope (see below) are met. Please note that the stranding effect at this type of shoreline may occur from all types of vessel wakes generated by deep-draft vessels, as well as from small fishing and pleasure boats.

Configuration of a bank slope that may indicate the existence of a fish stranding effect also is preliminarily identified as a combination of a steep deep water slope and shallow underwater terrace with no or a small upper beach. Vessel wakes propagate a long distance along this slope with small dissipation. When a vessel wake arrives at the shoreline, the upland-directed hydrodynamic force is still significant and capable of trapping fish and forcing the fish toward the upper bank.

The above fish stranding indicators are likely applicable to the upstream part of the Barlow Point shoreline. This part of the shoreline is in close proximity to the river bend, and the bottom slope is composed of a steep slope in combination with a flat and shallow underwater terrace. There also was none or minimal upper beach observed at this part of the shoreline. The physical condition indicators explain hot spots of fish stranding observed at this part of Barlow Point shoreline from previous studies.

In contrast, a gradual and uniform beach extending deep into the river may be an indicator of none or very limited fish stranding capacity. Interaction of vessel wakes with this type of beach slope causes an effective transformation of kinetic energy. As a result the upward- directed hydrodynamic force from the vessel wake arriving at the upper part of shoreline is reduced and not sufficient to generate a fish stranding effect. Thus, the fish stranding effect at this type of shoreline is minimal. County Line Park, Sauvie Island, and the downstream portion of Barlow Point shorelines represent this type of morphologic composition. Fish stranding at these areas is low compared to Barlow Pt.

4. References

Ackerman, N.K. 2002. Effects of vessel wake stranding of juvenile salmonids in the lower Columbia River. A pilot study: Report by SP Cramer & Associates, Inc., Sandy, Oregon, for the U.S. Army Corps of Engineers, Portland District, Portland, OR.

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