Hydropower Development at Fixed Crest Dams: An Evaluation of Wetland Impacts

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INTRODUCTION

As energy demand in the United States increases, hydropower is commonly called upon as a relatively clean and innocuous alternative. An Environmental Impact Statement published in 1988 (Federal Energy Regulatory Commission) assessed cumulative and site specific effects of 24 proposed hydroelectric projects at 19 sites in the Ohio River Basin. Of the 19 sites, 9 are proposed for non-gated, or fixed crest dams. Six of these projects control pool levels associated with significant wetland resources.

Most rivers in the eastern states with flows sufficient for hydropower development have, over a period of years, been dammed for the creation of lock systems for river navigation and flood control. Therefore, new hydropower developments are commonly proposed as retrofits at existing dams, rather than as part of new structures.

Existing dams were typically constructed with navigation locks, and have gated or fixed crests. Gates allow dam height to be manipulated to alter pool levels and therefore provide floodwater storage capacity. Non-gated, or fixed crest dams were developed primarily for the establishment of navigable pools, and do not provide flood control. Pool level behind these dams is controlled by the depth of water flowing over the dam face, and the amount of water released through navigation locks.

With the creation of pools behind fixed crest dams, water levels rose to approximate dam height, and the original floodplain terraces and riparian communities were permanently flooded. In many instances, these dams were constructed in the first half of the 20th century. New floodplains and wetland communities have since developed, and they depend upon existing pool levels and flooding regimes for maintenance of hydric conditions.

When hydropower developments are constructed at existing fixed crest dams, pool levels change. "Without hydropower, the pool elevation is controlled by the depth of water passing over the dam crest, which increases with increasing river flow. With hydropower, some of the flow passes through the dam to the turbines, effectively reducing over-dam flows" (FERC 1988). Therefore, pool levels continue to vary with daily and seasonally changing river flows, but pool levels are reduced by the amount of water passed through the hydropower plant. The lowering of pool levels from flow passing through the turbine, rather than over the dam, is referred to as drawdown. In general, the amount of drawdown is inversely proportional to river flow: pool level drawdown is insignificant at high flows, and more pronounced at moderate flows. At higher river flows, only a small proportion of total flow passes through the turbines. Consequently, wetlands sustained by infrequent high-river flows should be relatively unaffected; areas sustained by moderate flows are more likely to sustain impacts.

Little detailed information is available on the effects of hydropower-induced pool level changes on riparian wetlands. The problem can be exceedingly complex because of the interactions of the variables involved: river and wetland hydrology, adaptability of wetland vegetation, and hydropower plant engineering specifics. This situation is therefore much more complex than the wetland manipulations commonly performed on managed waterfowl marshes, and the frequently studied responses of various plants to periodic inundation.

This paper chronicles the complexity of the impacts to wetlands caused by hydropower development at fixed crest dams, which to our knowledge has not been previously assessed, and provides preliminary data from a case study initiated on the Allegheny River in Pennsylvania.

ALTERATIONS OF RIVER HYDROLOGY AND POOL LEVEL CHANGES

Unlike hydropower plants on gated dams, which can utilize stored water for power generation, plants at fixed crest dams use only "run-of-the-river" flows for power generation. During periods of extremely low flow, most hydropower plants do not operate, minimum over-dam flow is maintained, and no drawdown occurs. With higher flows, increasing quantities of water are drawn through the plant turbines to generate electricity. Significant drawdown occurs as the amount of water that passes through the hydropower plant increases until maximum intake capacity is reached. At river flows that permit intake in excess of plant capacity, the percentage of total flow passing through the turbines is small, and only limited drawdown is realized. At very high flows, the plants are shut down. Energy production ceases because the height of water in the pool below the plant approaches that in the pool above the dam, and there is little kinetic energy, or "head," available for generation of electricity. Therefore, post-project pool levels will approximate pre-project levels during extremely low flows. At moderate flows, drawdown will be most pronounced. With extremely high flows, drawdown will not occur, and pool levels may actually increase if dam length is shortened by installation of hydropower facilities (Figure 1).

An understanding of pre- and post-project pool levels during various times of the year is important when assessing potential impacts to

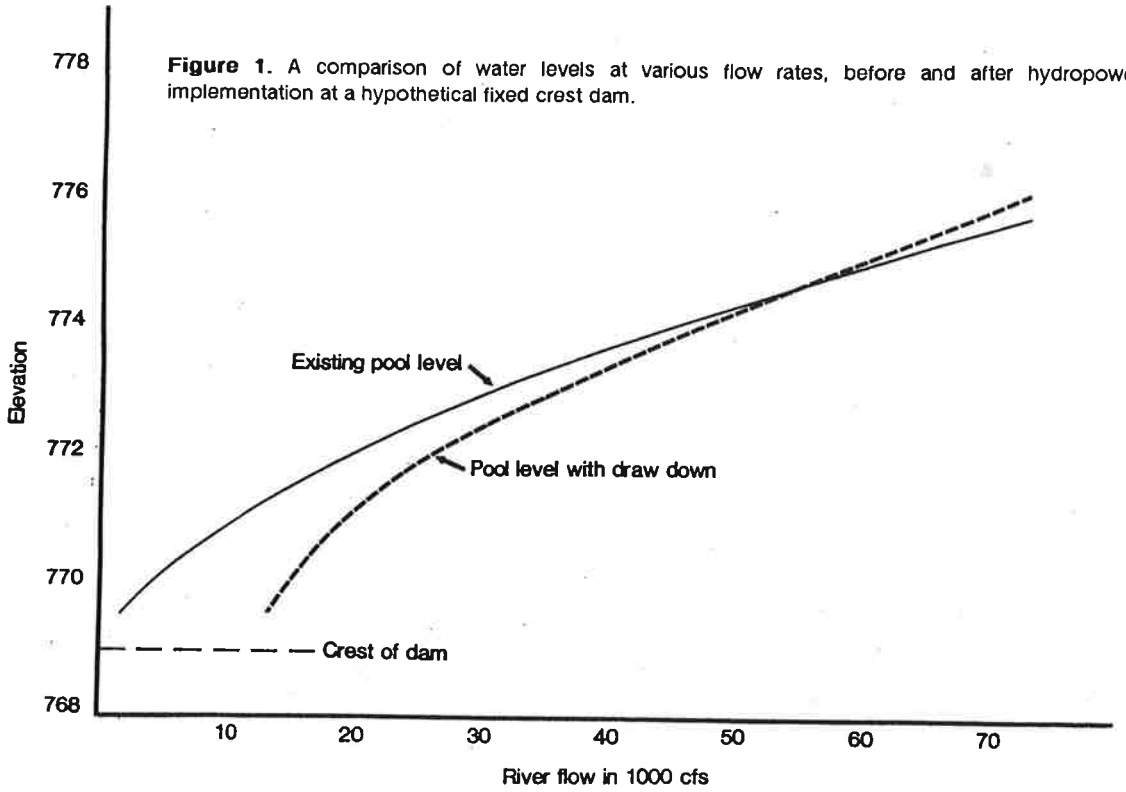

Figure 1. A comparison of water levels at various flow rates, before and after hydropower implementation at a hypothetical fixed crest dam.

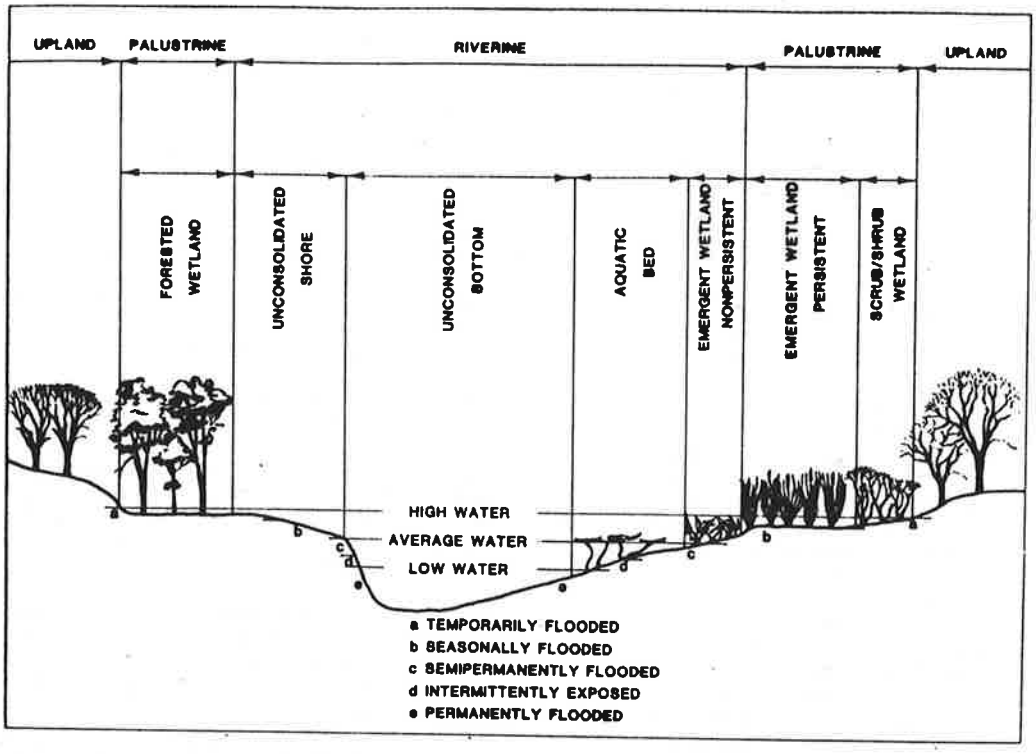

Figure 2. Typical riparian wetland types along dammed rivers (Cowardin et al. 1979).

wetlands. Average flow rates can be used to predict pool level changes on a monthly basis to determine whether drawdown occurs during the growing season. If drawdown is significant during the growing season, impacts on wetlands are likely. However, impacts will be limited if measurable drawdown occurs only when wetland vegetation is dormant. Drawdown also varies with distance behind the dam. For the normal range of river flows, decreases in pool level are more pronounced closer to the hydropower unit. Wetland impacts vary not only with location relative to the hydropower unit, but more importantly, with topographic elevation relative to pool levels.

Pool level changes with implementation of hydropower at fixed crest dams can be controlled, but typically vary with both river flows (season of the year), and proximity to the dam. Predicted changes under typical conditions are presented below.

River Flows	Pool Level Change	Comments
very low	slight increase	due to decrease in dam length, plant is shut down
low	slight decrease	limited through-dam intake to maintain over-dam flow
moderate	largest decrease	over-dam flow maintained, but higher percentage of river flows are drawn through dam
high	decrease	through-dam flows are an insignificant proportion of river flows
very high	slight increase	due to decrease in dam length, plant is shut down

Pool levels change behind fixed crest dams with through-dam flows. However, if a fixed crest dam is altered to support gates, pool levels can be temporarily raised, and drawdown regulated to approximate pre-project level. "Flashboards are removable boards mounted vertically along the dam crest to raise the effective height of the dam" (FERC, 1988). Traditionally, the use of flashboards has not been favored because of questionable reliability and the potential for undesirable stresses and effects on the dam structure, including drying of the downstream face of the dam, freeze and thaw damage, and potential unbalanced over-dam flow leading to increased scouring at the toes of dams. Flashboards also increase the operating complexity of the dam. Because they are mounted on dams not originally designed to tolerate the stresses of gates, flashboards are mounted to break away during floods, and therefore must be removed when high flows are predicted. By "artificially" maintaining higher pool levels, flashboards also reduce the head available for power generation at the next dam upstream (FERC, 1988).

CHARACTERISTIC RIPARIAN WETLANDS

Riparian floodplains associated with dammed rivers are typically dominated by palustrine emergent and forested wetlands, with submersed communities in shallow water classified as riverine or lacustrine (Cowardin et al. 1979). The wetlands develop in areas with specific hydric conditions governed by their topographic relationship, or relative elevation, to river and groundwater levels. Wetlands in a model riparian community could include: submersed aquatics, an unconsolidated shoreline or nonpersistent emergents consisting primarily of pioneer species, persistent emergents on slightly higher floodplain areas, and scrub/shrub and forested areas grading into nonhydric uplands (Figure 2).

Submersed aquatics, by definition, flourish under continuous inundation. Shoreline emergents, however, grow in shallow water or saturated soil, and may frequently be inundated by rising river levels. Scrub/shrub and forested wetland communities can be expected in relatively elevated areas that may be only temporarily or seasonally flooded, but rarely incur sustained inundation. Hydric conditions in these areas may be sustained more by groundwater levels than by surface inundation (Reid and Wood 1976; Cowardin et al. 1979).

Because riparian wetlands depend upon high water tables and occasional inundation by river flows, lowered pool levels and decreased soil moisture caused by hydropower drawdown can adversely affect these areas. However, impacts to wetlands caused by decreased soil moisture are much less dramatic and obvious than stress associated with an increase in flooding (Bedinger 1978), and impacts may be discernable only over long periods of time.

Submersed or emergent wetland communities established in shallow water may be most profoundly affected by relatively slight decreases in traditional pool levels. Substrates exposed by pool level drawdown will dry and will no longer be suitable for many species. Impacts to wetlands near average pool level during the growing season will likely be most obvious as new shoreline flats are exposed by reduced water levels. Emergent wetlands will likely expand toward the river when lower pool levels persist. An increased frequency of plants successful in slightly drier sites, probably an encroachment of woody species from forested wetlands, may be noted in the upper reaches of these wetlands as frequency of inundation and soil moisture levels decrease. Because these wetlands may serve as reproductive areas for river fish, a temporary loss of this habitat may occur until vegetative communities reestablish themselves.

Changes in palustrine forested wetlands are most difficult to discern. These wetlands can occur from near water line to the upper edge of hydric conditions, and are sustained by groundwater and infrequent inundation during the growing season. Because through-dam flows are an insignificant proportion of high river flows, and the construction of hydropower units may decrease the effective length of the dam, the height and

Table 1. A comparison of pool levels before and after hydropower development at a fixed crest dam, Pool 6 of the Allegheny River, Pennsylvania.*

	Upper Pool Levels			Lower Pool Levels		
Flow Rate (cfs)	Existing	Proposed	Change (ft.)	Existing	Proposed	Change (ft.)
1,000	769.5	769.6	+0.1	757.5	757.6	+0.1
5,000	770.2	769.6	-0.6	758.6	757.7	-0.9
10,000	771.0	769.6	-1.4	759.6	757.9	-1.7
15,000	771.5	770.1	-1.4	760.5	758.6	-1.9
20,000	772.0	771.2	-0.8	761.2	760.0	-1.2
30,000	773.0	772.4	-0.6	762.6	762.0	-0.6
40,000	773.7	773.4	-0.3	763.9	764.0	+0.1
50,000	774.3	774.2	-0.1	765.1	765.1	0.0
120,000	778.3	779.1	+0.8	772.3	772.9	+0.6
217,000	783.3	784.1	+0.8	781.2	781.6	+0.4

* Yearly mean flow rate = 14,882 cfs, with highest flows in March (apx. 33,800 cfs) and lowest flows in August (apx. 4,800 cfs). Estimated one year flood flows approximate the 120,000 cfs data.

frequency of flood flows reaching these wetlands should be unchanged or slightly increased by project implementation. Therefore, wetlands sustained only by occasional inundation are likely to be perpetuated, and significant changes in character or functional values should not be expected.

Hydropower implementation at fixed crest dams is not expected to cause large net losses of riparian wetlands. Following project initiation and pool drawdown, a transition period is expected, during which wetland communities will "move" along the vertical gradient of soil moisture and river levels. This process will be slow and difficult to document in forested areas, but may occur over one growing season in wetlands dominated by herbaceous plants. The size of riparian wetlands could increase, and the types of wetlands may change with new hydric regimes. Emergent shoreline and vegetated unconsolidated shore areas may increase in areal extent as soils are exposed by decreased pool levels. This process will also expose shallow water areas that supported submersed aquatic communities. Unlike a gated dam, a fixed crest structure will not provide for alteration of pool levels independent of river flow. Therefore, an increase in unvegetated, wave-washed shoreline is not expected.

A CASE STUDY

Beginning in 1987, wetlands along 9.4 miles of both shores of Pool 6 of the Allegheny River, Armstrong County, Pennsylvania, were delineated, mapped, and photographed. This baseline inventory was completed to initiate monitoring of wetland changes following installation of a hydropower plant in Dam 6, a fixed crest facility. Hydrologic modeling of pre- and post-project water levels by river flow (cfs) and by month had been previously completed. To help predict which wetlands are associated with large, relatively flat submersed topography which would be exposed by drawdown, bathymetric measurements were made along transects running from shoreline wetlands toward mid-river.

Table 2. Estimated average reduction in pool elevations with operation of a hydropower unit at a fixed crest dam on Pool 6 of the Alleghany River, Pennsylvania. Elevations are expressed as a function of median monthly flows.

Month	Median flow (cfs)	Change in pool elevation (in.)
October	6,550	-13.2
November	15,000	-22.8
December	22,300	-15.6
January	15,200	-13.2
February	15,800	-13.2
March	30,200	-12.0
April	22,800	-12.0
May	14,800	-15.6
June	8,380	-15.6
July	6,110	-12.0
August	4,970	-9.6
September	5,000	-9.6

The topography along this section of the Allegheny River is relatively severe. Steep sided valleys occasionally continue below river level. Broad, expansive floodplains are not common, but do exist on both sides of the river. River hydrology was characterized by flow modeling which predicted post-project water levels, pool level drawdown at varying flows, and positions in the pool by month of the year (Tables 1 and 2). With project implementation, water levels will range from 9.6 to 15.6 inches lower during the growing season than prior to drawdown.

Typical riparian vegetation consists of long, narrow, linear shoreline bands, with three distinct zones: (1) submersed aquatic beds growing at depths up to six feet, (2) annual herbaceous growth at pool level backed by perennial grasses and forbs on slightly drier soils, and (3)

scrub/shrub or forested wetlands grading into upland. Presence of these community types is inconsistent, as submersed growth is relatively uncommon, and scrub/shrub growth often dominates at pool level.

Common wetland species in the study area include Eurasian watermilfoil (Myriophyllum spicatum), water stargrass (Zosterella dubia), and curly pondweed (Potamogeton crispus) in submersed communities; water willow (Justicia americana) in shallow water; annual herbs such as pony grass (Eragrostis hypoides) and pale smartweed (Polygonum lapathifolium) on exposed shoreline flats in saturated soils, with reed canary grass (Phalaris arundinacae) in slightly higher areas. Scrub/shrub wetland areas include sandbar willow (Salix interior), and black willow (S. nigra). Palustrine forested wetlands are dominated by facultative or facultative wetland species, primarily silver maple (Acer saccharinum), sycamore (Platanus occidentalis), cottonwood (Populus deltoides), and green ash (Fraxinus pennsylvanica).

It is predicted that the greatest impact will occur in forest, shrub, and herbaceous pre-implementation shoreline wetlands, and submersed wetlands in shallow water. Submersed wetlands in shallow water will be exposed by drawdown, and substrates will dry. These areas will become exposed shoreline flats and will be colonized by emergents. If shoreline topography is gradual, extensive flats will be exposed by pool drawdown. The exposed mineral soils are productive seed beds for a variety of riparian plants, and will likely be colonized within one growing season by pony grass, smartweeds, or other similar species. Although short-term impacts to wetlands in the study area are not expected to be significant, short-term reductions in the areal extent of submersed communities is likely, and shoreline wetlands are likely to expand during the first growing season to cover exposed areas. Some loss of important fisheries habitat used for reproduction and foraging is likely, but these habitats are expected to again become available as wetlands recover. The Cogley Island Wetland Complex in Pool 6 is of special concern because past surveys have shown use of the extensive water willow beds by game and forage fish, and various other aquatic biota. However, water willow beds are expected to recover quickly, as the species can spread up to five feet per year via an extensive cord-like rhizome. Long-term gains, therefore, should approximate short-term losses. Predicted long-term effects do not include a significant change in the ratios of wetland types, loss of wetland areal coverage, or reduction in functional values.

CONCLUSIONS AND RECOMMENDATIONS

Impacts to wetlands resulting from hydropower implementation at fixed crest dams are complex because they involve river and wetland hydrodynamics and relative topography, adaptability of wetland vegetation to hydrologic modification, and design and operating specifics of the hydropower plant. Drawdown is minimal at very low and very high river flows, and is most pronounced at low and moderate flows. Impacts to wetlands can occur if hydrology is modified by drawdown during the growing season. Impacts will vary with elevation of the wetland relative to normal pool height. Wetlands sustained by groundwater and periodic inundation by high river flows are not likely to be significantly impacted; however, those areas sustained by specific hydric conditions present at shoreline elevations are expected to be adversely affected. Under most circumstances, long term reductions in wetland areas are not expected but some wetlands may change as their boundaries "move" to adjust to new hydrologic conditions.

Therefore, although impacts will vary with each project, we recommend that the interactions discussed here be examined. Impact mitigation should be focused on short-term impacts, and should include measures to replace or enhance habitat quality and quantity until important wetlands recover.

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