Journal of Environmental Management xxx (2008) 1–9

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: www.elsevier.com/locate/jenvman

Using hydraulic modeling to address social impacts of small dam removals in southern New Jersey

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A R T I C L E I N F O

Article history:
Received 4 November 2007
Received in revised form 6 May 2008
Accepted 30 July 2008
Available online xxx

Keywords:
Small dams
Social impacts
Dam removal
Mantua Creek
Hydraulic modeling
New Jersey

A B S T R A C T

Small relic mill dams are common in the watersheds of southern New Jersey, dotting the landscape with many small neighborhood lakes. Originally built in the late 1800s, most of these dams have become increasingly unable to handle current design storms due to increased urbanization of the watersheds. Several of these dams have also been classified as "high hazard" by the New Jersey Department of Environmental Protection Dam Safety Division because their failure has the potential for loss of life or extensive property damage. The current private owners are generally unable to afford the high repair costs needed to rehabilitate the dams to current safety standards, and are therefore more inclined to remove them. This research analyses both the physical and social impacts of the removal of two small dams in southern New Jersey, and integrates the two seemingly disparate concepts. Using hydraulic modeling and previous case studies, it is predicted that there will be limited effects to the hydrological and biological characteristics of the stream corridor. A survey distributed to the affected homeowners that live on these lakes shows that the community, however, expects significant impacts to the bio-physical characteristics of the stream corridor, as well financial impacts to their property value and social impacts to their recreational activities. The current study exposes the widening gap between policy makers and landowners, and highlights where complete stakeholder interaction could and should occur.

1. Introduction

There is an emerging realization in the science of dam removal that the competing demands and goals between scientists, policy makers, and stakeholders should be balanced (Poff et al., 2003). For example, Doyle et al. (2000) examined the critical issues surrounding the removal of a small dam in La Valle, Wisconsin and showed that they differed between the lakeside community and the scientists. Scientists and policy makers tend to consider environmental and safety issues as the critical factors in the decision to remove a dam, while homeowners around lakes tend to decry the loss of wildlife and aesthetics as their biggest concerns. Typically, the latter issues are not considered to be strong enough to affect the decisions of the policy makers. In their analysis of the removal of 30 small dams in Wisconsin, Born et al. (1998) noted that resident views were typically not taken into consideration and that the information presented by the government agencies tended to be biased towards removal. Recent studies in Pennsylvania and Oregon analyzing the removal process of small dams, however, have reported successes of involving and collaborating with all the stakeholders throughout the entire process (Bushaw-Newton et al., 2002; Smith et al., 2000).

Projects involving the removal of small dams are fast becoming the critical focus for new river science and policies (Doyle et al., 2003). Most dams in this country that have been removed to date have been small dams with a median height of about 3 m (Donnelly et al., 2002). Environmental concerns that may dominate on large dams are typically less of an issue for small dams. Recent studies have shown that the removal of small dams will have limited or temporary negative impacts on such riverine functions as fish habitat and community (Kanehl et al., 1997), invertebrate habitat and community (Thomson et al., 2005), and channel form (Stanley et al., 2002). The part of the ecosystem that generally requires the longest recovery time is the riparian vegetation (Doyle et al., 2005), and non-native plants tend to dominate the re-growth within the old lakebed if left unchecked (Orr and Stanley, 2006). Therefore, the potential safety hazards that could result from a failure of these small dams are the primary reasons for removal (Donnelly et al., 2002; Bowman, 2002), despite that the option of repair is generally preferred by stakeholders (Born et al., 1998). It should be noted that, typically, state agencies cannot order the removal of dams, but can demand that the safety issue be corrected (Bowman, 2002). For

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0301-4797/$ – see front matter Published by Elsevier Ltd.
doi:10.1016/j.jenvman.2008.07.027

small, privately owned dams, removal is often the option selected, however, because of lower associated costs than for repair (Born et al., 1998).

Dam removal projects, particularly small dam removals, are typically undertaken with little concern for the affected landowners (Born et al., 1998; Doyle et al., 2000). Most small dams in New Jersey are privately owned, but the lakes they form may be girded by other private homeowners. These dams typically are relics from the late 1800s milling industry. When the mills closed down, the impounded lakes behind these dams found other uses, such as irrigation or aesthetics, to maintain their importance in the area.

2. Objectives

The research discussed herein is a predictive analysis of the physical effects that the removal of two small dams will have on urbanized stream corridor in southern New Jersey. To this end, hydraulic models, sediment analyses, and comparisons with similar case studies are used. These analyses may show the physical impacts of the removals, but nothing of the social impacts. In general, little attention has been given to the socio-economic impacts of small dam removal projects around the country (Born et al., 1998), but recent efforts, however, are serving to change that (*e.g.*, Doyle et al., 2000; Poff et al., 2003). Other recent studies have strived to reconcile public conceptions and/or misconceptions with hydrologic modeling (*e.g.*, Calder et al., 2004). Bednarek (2001) cites a general lack of community appreciation for the value of dam removal on the stream corridor and suggests more informational programs be instituted. The physical modeling of these dam removals can be used to address some of the social impacts of the surrounding homeowners. The critical issues and concerns that the affected homeowners have on the removal of their neighborhood dams were synthesized, and for any misconceptions or misgivings the local residents may have on dam removal, the physical models were used to address them.

3. Methods

3.1. Setting – Upper Mantua Creek Watershed

The study area includes two headwater tributaries of Mantua Creek – Upper Mantua Creek and Duffield Run. Located in southwest New Jersey, Mantua Creek flows northwest towards its junction with the Delaware River (Fig. 1). The study area encompasses about 19 square kilometers and is contained within five municipalities: Washington Township, Glassboro Borough, Pitman Borough, Mantua Township, and Monroe Township. The mainstem, which extends from Glassboro-Cross Keys Road past Lambs Road, drains approximately two-thirds of the study area, while the remaining area is drained by its tributary, Duffield Run, which flows from upstream of Fish Pond Road to its confluence with the mainstem at Sterling Lake. A USGS streamgage (USGS Station ID 01475000) that has collected continuous daily flow statistics since 1941 is located just downstream of Wadsworth Dam (Fig. 1). According to this gage, the mean annual flow for Mantua Creek is 0.33 m^3/s. The average channel slope is approximately 0.4%. The dominate channel soils are sands mixed with some silts and gravels (average grain size is about 0.55 mm). The average shear stress in the channel is about 0.15 N/m^2 at bankfull stage. Due to other downstream impedances, there are no anadromous fish present in this section of Mantua Creek.

The watershed includes several small artificial lakes and ponds (Fig. 1). All of the dams in the watershed are between 2 and 4.5 m high. These lakes and ponds are all within the run of the river and many were constructed as millponds during the 19th or early 20th century. These lakes and ponds serve to level the water surface slope and collect sediment, but provide little stormwater storage due to their small volumes (See Section 4.2).

The topography of the watershed is relatively flat with a few rolling hills at the headwaters. Prior to 1970s, the land use was dominated by agriculture. Based upon NJDEP (New Jersey Department of Environmental Protection) land use data, over the past forty years, urban development has increased from 45% to 67% of the watershed while agriculture has decreased from almost 30% to less than 10%. This decrease in pervious land cover has led to increases in peak runoff volumes in Mantua Creek.

3.2. Wadsworth and Sterling Lake Dams

The two dams of interest in this watershed are Wadsworth and Sterling Lake Dams (Fig. 1). Both dam structures are almost 3 m in height. Like most dams in the area, they are relic mill dams that date back to the 1800's. Both have been privately owned since at least 1935, but are regularly inspected by the NJDEP to ensure they meet current safety standards. Any renovations or removals would be financed by the private owners, not by the county or the homeowners that live on the lakes. There is no public access to either lake limiting their recreational benefit to the broader community. Because most of the homes around these lakes were built within the past forty years (i.e. since after the dams have been present), the homeowners purchased their properties as lakeside houses, and their property lines are delineated to the center of the lakes.

In July 2004, a large rain event that produced over seven inches of rain in a 4-h period occurred in southern and central New Jersey. The excess runoff quickly overwhelmed many of the small streams and reservoirs in the area. As a result, thirteen small dams failed catastrophically. In response to these failures, the NJDEP Dam Safety Division completed safety inspections on all the remaining dams. Wadsworth and Sterling Lake Dams were determined to be structurally deficient to withstand the current peak runoff volumes. Both dams were also found to exhibit the potential for extensive property damage if they too were to catastrophically fail. The main potential for property damage is the two immediately downstream road crossings from Wadsworth Dam – Delsea Drive and Holly Avenue (Fig. 1). Both dams were therefore classified as "Class I – High Hazard", which is defined as one in which a failure will result in probable loss of life and/or extensive property damage (see the NJDEP website http://www.state.nj.us/dep/nhr/engineering/damsafety for more details on dam classification). NJDEP regulations state that dams of this classification must have their hazard potential eliminated, either by removal or rehabilitation that reduces the failure risk. Since the dams don't generate income from such uses as hydroelectric power, farming or recreational activities, the more economic (i.e. cheaper) option was to remove them completely. These decisions were made without consult from the homeowners that live around the lakes. To prevent any calamities along the stream corridor before the dams are removed, the owners took actions to reduce their storage capacity. The flash boards on Sterling Lake Dam were removed so that the spillway is all that remains. At Wadsworth Dam, the gate valve at the bottom of the dam was completely opened. These partial structures still maintain some upstream storage during high flows, but drain the lakebeds completely during the low flow summer months.

3.3. Resident questionnaires

In an effort to better understand the homeowners' opinions and concerns on the social, economic, and environmental issues surrounding the removal of the dams in their community, a non-scientific questionnaire was delivered to each residence that bordered on Wadsworth and Sterling Lakes. There were no direct

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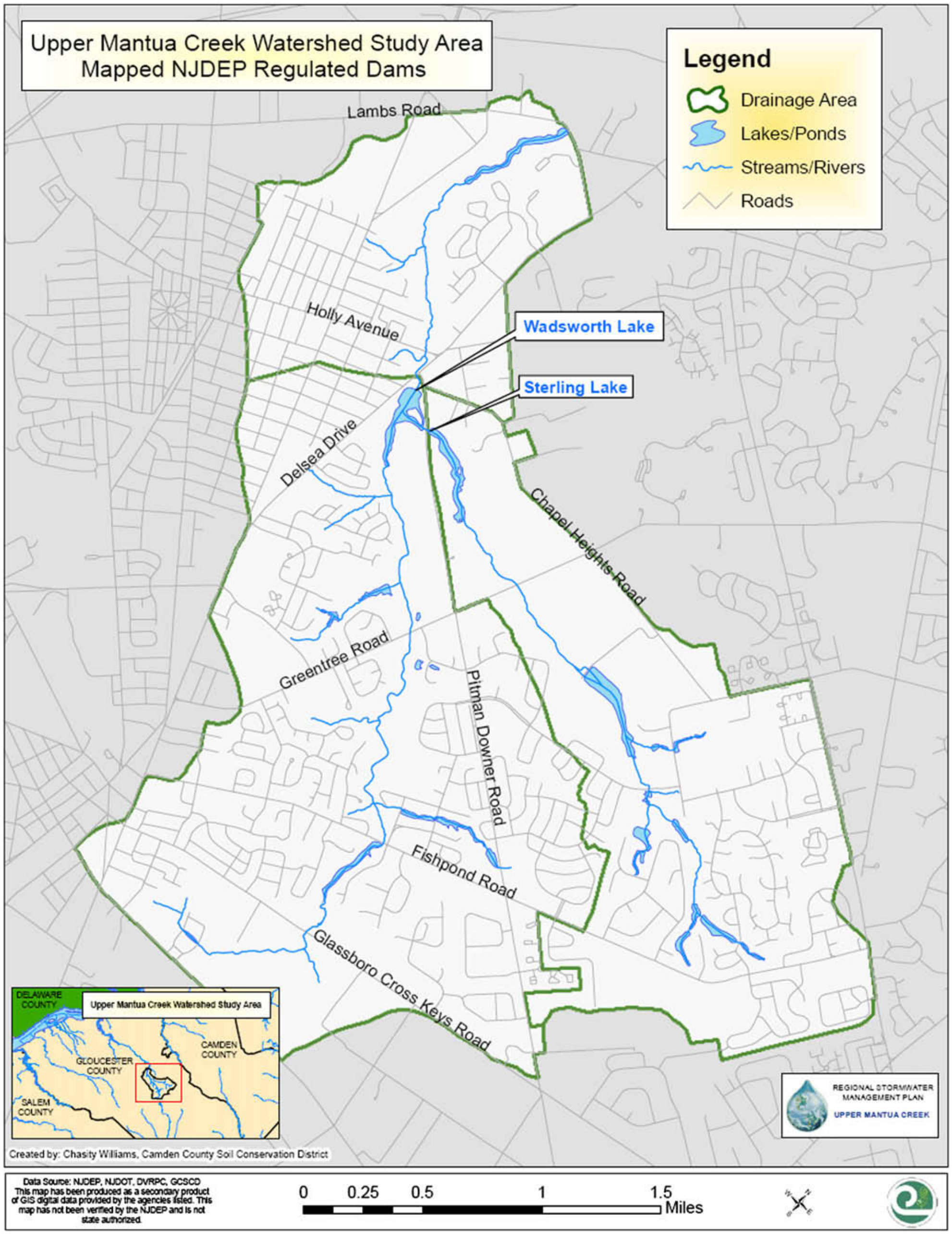

Fig. 1. Map of Upper Mantua Creek Watershed.

interviews, as each respondent completed the questionnaire and mailed the form back. The questions were meant to derive the residents' relationships with the lakes on which they lived. They were asked to describe their recreational use of the lakes, the financial advantage the lakes gave their home, whether they knew of the removal situation and their opinions of it, as well as to discuss any and all other thoughts on the removal project in general. This facilitation of stakeholder participation closely mimics the guide that Braun et al. (this issue) outlines for socio-economic assessment for large dam removal impacts. Despite the differences in scale, the processes are shown to be similar.

3.4. Numerical modeling of dam removals

Two hydraulic and hydrologic routing models, HEC-RAS and HEC-HMS (Hydrologic Engineering Center, Davis, CA), were simultaneously used to simulate peak flows through the stream corridor for a variety of potential dam breach configurations. Both models perform one-dimensional analyses for steady and unsteady flow conditions. HEC-RAS uses known channel geometry, channel roughness and stage-discharge rating curves as boundary conditions to calculate water surface profiles for any given flow condition. This model can also estimate the expected sediment loading and total sediment movement for known channel geometries and sediment characteristics. The hydrologic boundary conditions for the HEC-HMS model are rainfall input and known watershed characteristics, such as land use, soil type, and topography. This model has several accepted mathematical models to choose from in which to estimate surface runoff for any dendritic channel system.

The culverts and dams in the Mantua Creek watershed were modeled as specified in the HEC manual. The suite of channel geometries used in the HEC-RAS model was determined by

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systematic field surveys along the stream corridor and by aerial surveys for the lakebeds. The channel roughness values used in the HEC-RAS model were initially estimated using the procedures in the New Jersey Standards for Soil Erosion and Sediment Control (NJ Dept. of Agriculture, 1999). The model was then calibrated by adjusting these channel roughness values until the predicted stages and velocities matched those observed for field-measured events. The final values used in the model were then compared to actual conditions to ensure validity. The HEC-HMS model was calibrated for individual storms by adjusting the soil imperviousness and runoff lag times within the watershed until peak flows matched those observed at the USGS gaging station at Wadsworth Dam. These final modeled values were also field-verified for validity.

Flow through and downstream of Wadsworth and Sterling Lakes were first modeled for their current conditions and their conditions prior to the opening of the gate valve at Wadsworth Dam and the removal of the flash boards at Sterling Lake Dam. Because neither dam has been removed as of press time, it is unknown what the exact breaching configuration for either dam will be. Sterling Lake Dam is expected to be completely removed, but the concrete structure at Wadsworth Dam is likely to only be partially removed. Several possible modifications were simulated and compared (Fig. 2). For each potential modification at Wadsworth (Fig. 2C), the spillway at Sterling Lake was modeled as completely removed (Fig. 2A). Each potential modification was modeled in HEC-HMS to determine their effect on the peak flow. These peak flows were then routed through the HEC-RAS model and the peak velocities and water surface elevations resulting from each potential modification were compared. It should be noted that this study is not meant to be a design for optimal spillway removal.

3.5. Reference reach comparison

While the numerical models can predict the impacts to the hydraulic characteristics of the stream corridor after the dams are breached, they cannot predict the stream morphology or the rate of re-vegetation for Mantua Creek. To understand the response of the newly exposed lakebeds behind the dams, and in the newly exposed backyards of the private homeowners, a similar site in an adjacent watershed is analyzed. Cartwheel Branch is a tributary to Raccoon Creek, which shares a drainage boundary with the Mantua Creek watershed. For safety reasons, Wrights Mill Lake , located on Cartwheel Branch, was lowered in late 2001 in accordance with the NJDEP Dam Safety Division requirements (Gloucester and Camden County Soil Conservation Districts et al., 2006). A permanent modification of the spillway structure was completed in 2003. The modified spillway allowed for the passage of baseflow and created insignificant changes to the 10 and 50-year storm discharges (from Drainage Calculations for Wrights Mill Dam Decommission – Prepared by Perks Reutter Associates, March 13, 2003). A stable stream channel has now formed in the former lakebed. Within one year or removal, new marshes and meadows formed that consist of mostly native emergent wetland species and new habitat has been created for a wide variety of wildlife (Fig. 3). Other than the modification of the spillway structure and riprap stabilization immediately around that area, no other restoration activities took place. The newly formed stream was surveyed for use as a natural stream restoration reference reach.

Wrights Mill Lake is located 8 km southwest of Wadsworth Lake, and exhibits similar hydraulic characteristics to Mantua Creek. The sand-bed stream has an average slope of 0.44% and an average

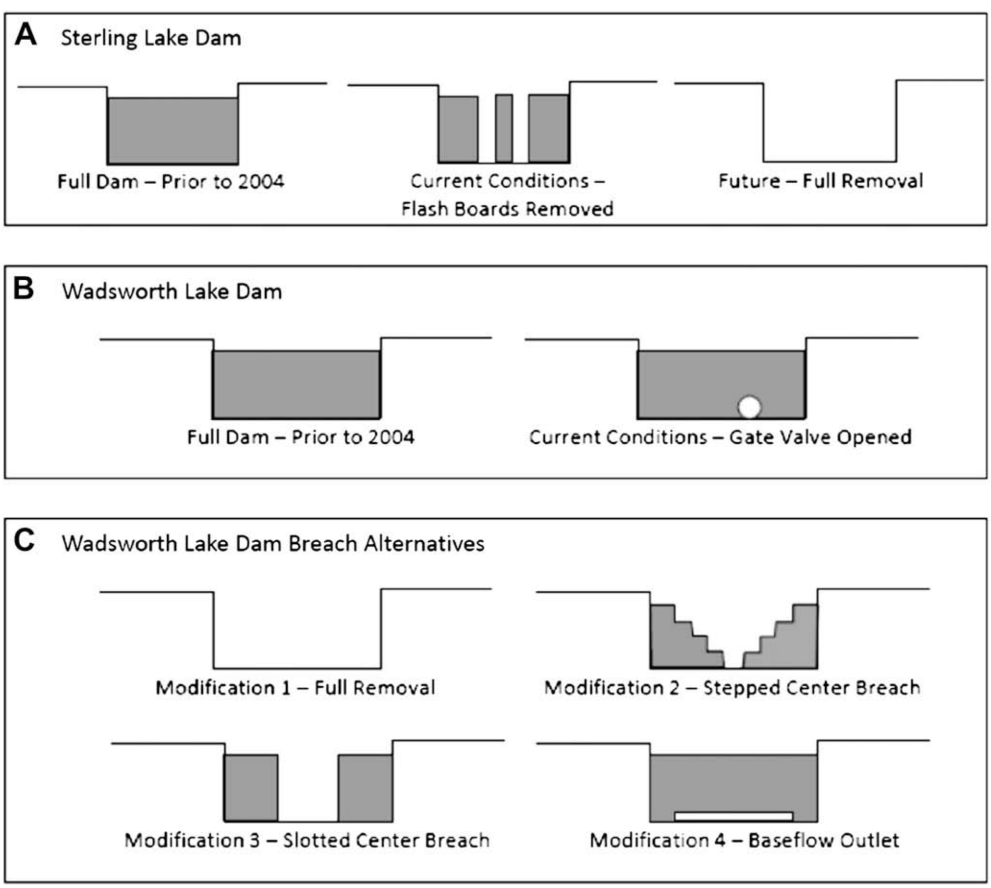

Fig. 2. (A) Prior conditions, current conditions, and expected full removal of Sterling Lake Dam, (B) Prior and current conditions of Wadsworth Dam, (C) Potential breach configurations of Wadsworth Dam, including full removal, stepped center breach, vertical slot center breach, and baseflow slot.

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Fig. 3. Re-vegetated lakebed one year after the removal of Wrights Mill Dam.

bankfull shear stress of 0.15 N/m^2 (Table 2). The objective of using this dam removal site in this analysis is to offer this hydraulically similar stream as anecdotal proof of the expected re-naturalization of Wadsworth and Sterling Lakes.

4. Results

4.1. Questionnaire responses

The informal survey returned a 44% response rate. Some of the more significant responses show the social and economical importance of the lakes to their property (Table 1). 72.7% of the respondents indicate that they purchased their house because of the lake, and 77.3% claim that their house cost more because of the lake. Almost 87% of the respondents feel that the loss of the lake will result in a significant reduction in their property resale value. A significant 90.9% of the residents are not in favor of the dams' removal. The percentage that responded 'yes' to that question (Table 1) indicated a preference in rehabilitation but understood that removal may be the best option. A varying percentage of the respondents claimed to have used the lake in the past for the suggested activities of boating (77.3%), fishing (86.4%), and wildlife viewing (95.5%), while several respondents added their own lake activities as well.

The final question on the survey (not indicated in Table 1) asked the respondents to discuss in their own words the issues they feel strongly about regarding the dam removals. By far, the most discussed issue was that the removal of the dams would cause a significant loss in wildlife and vegetation, which matches the concerns reported by Doyle et al. (2000). They are worried that their backyards will transform from a scenic lake into a mud hole in the future. This may be predicated on the fact that during the current dam conditions with the gate valve completely opened on Wadsworth Dam, there is no storage during the dry summer months. During this time, the lake level decreases and a typical stream forms through the sediments, leaving most of the lakebed exposed (Fig. 4). This situation only occurs for a couple months of the year, which does not give the riparian vegetation enough time to repopulate the area. Another common resident comment was for the expected loss of aesthetics. This comment may also be borne out of the above situation. The loss of recreation and property values were other common written complaints, but these were already delineated by the ordered questions in the first section. Residents also fear the rise of mosquito-borne diseases. When the lakebed begins to dry up in the current conditions, occasional pools of stagnant water are left stranded in the lakebeds, which become localized breeding grounds for aquatic insects.

Other exterior issues that arose included those concerning the loss of groundwater and loss of water for fire protection. Along the road that parallels the east side of Wadsworth, there are currently no fire hydrants and the local fire department drafts water from Wadsworth Lake for fire control when needed. An obvious concern of the residents, then, is their increased susceptibility to fire damages after the lakes are drained. Several residents use private groundwater wells and have noticed that the groundwater table has decreased since the lakes have been lowered, and they are concerned

Table 1
Resident responses to dam removal impact questionnaires

Questions	Response percent
How long have you lived at this address?	
Less than one year	4.5%
One to five years	13.6%
More than five years	81.8%
Did the fact that your house is lakefront have an impact on your purchasing it?	
Yes	72.7%
No	22.7%
Did your property have a higher value due to it being lakefront?	
Yes	77.3%
No	9.1%
Unsure	4.5%
Are you aware that the dams at Sterling & Wadsworth may be removed permanently draining the lakes?	
Yes	77.3%
No	22.7%
Are you in favor of the removal of the dams?	
Yes	4.5%
No	90.9%
No opinion	4.5%
Which activities have you used the lake for in the past?	
Boating/kayaking	77.3%
Fishing	86.4%
Wildlife appreciation	95.5%
Walking	45.5%
Aesthetics appreciation	4.5%
Ice skating	13.6%
Swimming	9.1%
Nature education	4.5%
If the lakes were to remain full, would you actively use the lakes?	
Yes	90.9%
No	9.1%
If the lakes were drained, how would it affect your recreation activities?	
Stop activity	86.4%
Find another lake	13.6%
If the lakes were drained, what do you believe will happen to your property value?	
Increase	0.0%
Decrease	86.4%
No change	9.1%
Unsure	4.5%
Are you aware that dams may provide downstream flood protection, but may also increase flood risk upstream?	
Yes	68.2%
No	22.7%

Table 2
Comparison of bankfull hydraulic characteristics between Mantua Creek and Cartwheel Branch

Hydraulic parameter	Mantua Creek	Cartwheel branch
Average stream slope	0.4%	0.44%
Average shear stress	0.154 N/m^2	0.146 N/m^2
Sediment characteristics	Coarse sand	Medium sand

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Fig. 4. Exposed lakebed of Wadsworth Dam following gate valve opening.

that they may have to dig deeper wells after the full dam removal. Several residents also questioned whether there would be increased downstream flood risk after the storage at these lakes are removed.

Several residents expressed frustration over not having any say in the final result of the dam. Despite the residents' recognition that the dam is privately owned, they decried the fact that the dams have been deemed unsafe due to increased surface water runoff into the system that was a direct result of county-approved urban development. They then question the validity of burdening the private owners of the dams with the rehabilitation/removal option when it was, in their view, the county that caused the problem with increased urbanization.

4.2. Numerical modeling

In general, dams are expected to mitigate storm surges, therefore, removing Wadsworth and Sterling Lake Dams might be expected to decrease the flood control on Mantua Creek and increase the risk of downstream flood damage. However, the numerical models used in this study indicate that neither water surface elevations nor the average velocities will be significantly affected at any cross-section upstream or downstream of the lakes regardless of the breach configuration (Figs. 5 and 6). These results suggest that the dams at Wadsworth and Sterling were providing little or no flood control for the system, i.e. the dams are small enough that they become washed out at high flows. Therefore, their removal will have insignificant impacts on the downstream corridor, especially with respect to the flood hydraulics at the Delsea Drive and Holly Avenue culverts downstream of Wadsworth Dam (Fig. 1).

Figs. 5 and 6 do not represent the entire stream corridor, only the reaches immediately upstream, downstream, and at Wadsworth Lake. The differences in the water surface elevations and average velocities become increasingly negligible further upstream and downstream of Wadsworth Dam, and do not warrant extending the figures. The only significant differences in the stream velocities that the models do show are through the old lakebeds (Fig. 6). These velocities have the potential to erode the impounded

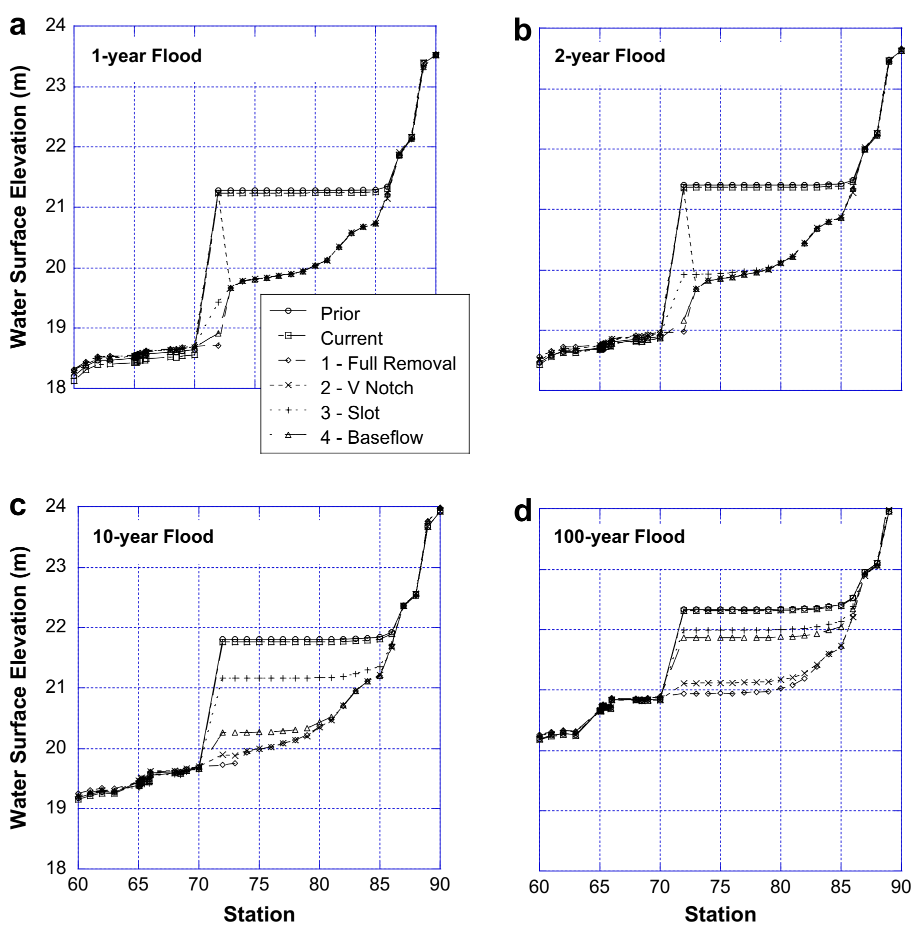

Fig. 5. Changes in water surface elevation for each dam modification as modeled by HEC-RAS for specified flood events (see dam modifications in Fig. 2). Wadsworth Dam is located at Station 71. The downstream culverts at Delsea Drive and Holly Avenue are located at Stations 67 and 64, respectively.

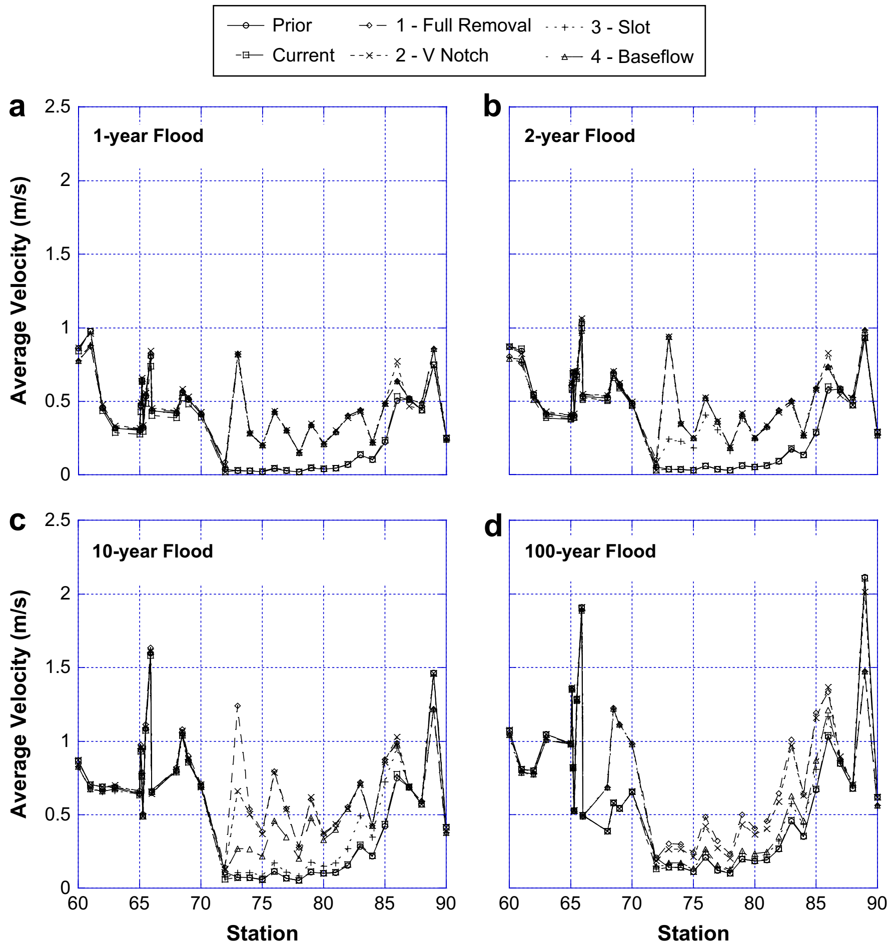

Fig. 6. Change in mean channel velocity for each dam modification as modeled by HEC-RAS for specified flood event (see dam modifications in Fig. 2). Wadsworth Dam is located at Station 71. The downstream culverts at Delsea Drive and Holly Avenue are located at Stations 67 and 64, respectively.

sediments in those reaches, which could increase the downstream sediment load. Alternatives for stabilizing or detaining these sediments may need to be assessed.

4.3. Formation of a stream corridor in the lakebeds

An evaluation of the stream corridors upstream and downstream of Wadsworth Lake was performed in order to determine what type of stream might evolve in the newly exposed lakebed behind Wadsworth Dam. The objective was to determine the potential for a headcut to form in the impounded sediment and the potential for excess downstream sediment deposition after the dam is removed. Important stream characteristics that may affect these potentials include sinuosity, channel slope, width-to-depth ratio, entrenchment ratio, mean sediment size, and number of channels (Rosgen, 1996). Sinuosity can be an indicator of potential flow energy dissipation, and channel slope is an indicator of the amount of energy available in the system. The reference reaches were found to be mostly single channels that tend to exhibit a low sinuosity of 1.2 (for reference, a completely straight channel has a sinuosity of 1.0). The reaches were found to be slightly entrenched (value of 2.2 for ratio of floodplain width to bankfull width), exhibit moderate to high channel width-to-depth ratios (12), and have a moderate water surface slope (0.004–0.007) (Delaware Riverkeeper, 2007). Bulk sediment samples were collected in and around Wadsworth Lake. The main channel consists of mainly coarse sand and fine gravel, while the lakebed consists of mainly coarse silts and fine sands.

To determine how much lakebed sediment will be evacuated to create this new channel, an estimate of the amount of impounded sediment is necessary. From aerial surveys, the surface area of Wadsworth Lake was estimated to be about 580-m long with an average width of 43 m. For an estimated average sediment depth of about 0.76-m, a conservative volume of the total impounded sediments is about 19,000 cubic meters. If the channel that forms in the lakebeds exhibits similar characteristics as those described above, then it is estimated that about 1400 cubic meters will be naturally evacuated downstream (Gloucester and Camden County Soil Conservation Districts et al., 2007). To minimize the potential for a headcut to migrate further upstream than the lakebed, it is recommended that the footing of Wadsworth Dam remain in place to act as a grade control structure (Delaware Riverkeeper, 2007).

During the summer of 2005, conditions were dry enough that the lakebed behind Wadsworth Dam became exposed, leaving only a small, slightly sinuous channel that measured approximately 5 feet wide and one foot deep (Fig. 4). The observable characteristics of this channel closely match those estimated by Delaware Riverkeeper (2007).

In the neighboring Cartwheel Branch, the new stream that formed in the old Wrights Mill Lakebed did not create an upstream-degrading headcut, nor did it adversely affect the downstream channel with any increased sediment load. The new channel characteristics closely match those of the rest of the watershed. Therefore, it could be expected that the characteristics of the channel that will form through the old lakebed sediments of Wadsworth and Sterling Lakes will be similar to those described

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above. The estimated lakebed sediment evacuation is not expected to degrade the downstream reaches.

5. Discussion

Most residents tend to be conservative when it comes to their communities. While it has been previously noted that a public that may have been against the construction of a local dam may well be against its removal some years later (Babbitt, 2002), this kind of "it's-here-now-and-we-like-it" sentiment cannot be considered in the cases of Wadsworth and Sterling Dams, since the dams pre-date the neighborhood. At these lakes, there are no pre-dam neighborhoods with which to compare, and the "it's-always-been-here" sentiment dominates. The nostalgia for the lakes is therefore quite high among the residents. Nostalgia, intertwined with lake aesthetics, are common issues that arise for local stakeholders around any small lake, and these concepts are difficult to quantify from a scientific or management point of view (Doyle et al., 2000).

The most common comment from the surveys given to the residents at Wadsworth and Sterling Lakes was their worry that their wildlife-rich lake would be transformed into a muddy marsh devoid of any wildlife but mosquitoes. Visual evidence from the Wright's Mill case shows that this is not the case. Already, at the upstream end of Sterling Lake, trees and grasses are beginning to repopulate the exposed lakebed one year after the flash boards were removed at the dam to drain the lake (Fig. 7).

Another common resident comment was their worry that flooding risk would increase at the downstream road crossings at Delsea Drive and Holly Avenue. The watershed models decisively show that the removal of the dams will have no affect on the hydraulics of large flow events (Figs. 5 and 6).

The effect that the dam removals will have on the local wildlife is difficult to currently predict. Certainly the lacustrine biota will be severely impacted, but peripheral evidence at Wrights Mill shows that overall diversity may not be affected. Currently, a study is underway to analyze and predict the impacts on the aquatic invertebrate populations.

A common complaint from the survey was the presence of the muddy marsh that now persists after the lake fills behind the Wadsworth retaining wall that is still in place then drains during the dry summer months. From the survey results it can be ascertained that this would not be an acceptable alternative to their lake. The watershed models, however, show that ponding will not be an issue for two of the four potential dam breach configurations (Fig. 2). If the prediction of the stream formation analysis is true, then a channel will cut through the impounded sediment,

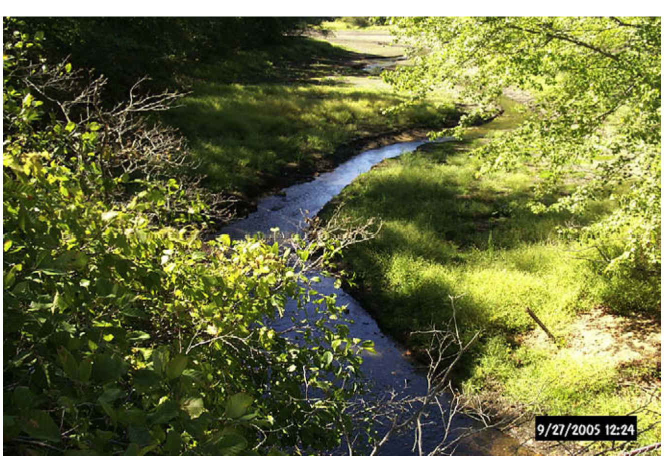

Fig. 7. Emerging riparian vegetation within Sterling Lake, one year after the flash boards were removed and the lake level lowered.

decreasing the chance even further for ponding. If there is no ponding, then there exists more chance for quicker re-growth of the riparian vegetation and less chance for future views of the muddy marsh.

6. Conclusions

The bio-physical impacts that may result from the removal of Wadsworth and Sterling Dams can be summarized in the following statements. (1) Wadsworth and Sterling Dams are not important structures in controlling flooding in Upper Mantua Creek, and therefore can be removed without significantly affecting the water surface elevations or mean channel velocities. (2) An analysis of channel characteristics shows that if the footing of Wadsworth Dam is left in place, then minimal upstream headcuts and downstream sediment deposition will occur. The footing will not affect the water surface elevations or mean channel velocities if left in place. (3) Riparian revegetation has already started in Sterling Lake. Nearby Wright's Mill Pond showed quick restoration of vegetation and habitat. Careful considerations must be made in the breaching configuration at Wadsworth Dam to ensure that no backwater ponding occurs and native flora and fauna are allowed to repopulate the lakebed in a timely manner.

The responses from the resident questionnaires show a discrepancy in their most critical issues from those of the policy makers. Some of the residents' responses exhibited distinctly angry and frustrated tones, which shows that they feel their views are not being considered in the dam removal decision process. Almost all the residents do not want the lakes to be drained, for a variety of reasons. The most common reason is that the residents purchased their homes with the assumption that the lake would always be there. Most residents paid more for the property because of the lake view, and expect that their property value will now decrease after the dams are removed because of the loss of aesthetics. Most residents lament the loss of wildlife habitat and are concerned that repopulation will not occur. Many residents are also concerned of the impact the dam removal will have on the stream hydraulics. The critical concern of the policy makers, by contrast, was the safety hazard that these dams possess if they were to fail.

There should and could be better communication between the policy makers, scientists, and landowners. By distributing a simple questionnaire to each residence on Wadsworth and Sterling Lakes, we were able to better appreciate their issues and concerns, and therefore better address them. Several of the residents' main points can be addressed by use of a bio-physical analysis of the system. For example, wildlife habitat can be expected to re-establish after the dams are removed, and downstream flooding will not be a significant issue. By soliciting responses from the residents, their other major complaint, that their opinions are not being considered, can also be addressed.

A follow-up round of distributed literature to the residents on Wadsworth and Sterling Lakes is planned. This will attempt to address their concerns by discussing many of the modeling results presented herein. The effectiveness of this is difficult to estimate, however, as few projects have attempted such a method before. It is hoped that this could assuage many of the residents, but it would dependent on the level of trust they have for the personnel responsible for the modeling. By letting the residents recognize that their opinions do matter, this method should at least allow more opportunities for constructive dialogue on dam removal alternatives between the stakeholders and governing agencies.

Organized project meetings may be poorly attended by the affected stakeholders. By distributing resident questionnaires, the stakeholders who have opinions on the dam removal project can respond in their own time and in their own words. The Wadsworth and Sterling Lake surveys returned a 44% response rate. This high

Please cite this article in press as: Wyrick, J.R. et al., Using hydraulic modeling to address social impacts of small dam removals in southern New Jersey, Journal of Environmental Management (2008), doi:10.1016/j.jenvman.2008.07.027

value should encourage this type of stakeholder interaction for future projects. By distributing surveys to stakeholders, it is anticipated that this will increase awareness of the current situation and increase participation in the ultimate fate of the dams. Eventually public meetings will be held and by analyzing survey results, it will allow regulators, government agencies and engineers to prepare and better address concerns during these meetings. It should be noted that, because these particular dams are privately owned, the final decision to replace or remove the dams is solely up to the owners, not the homeowners. From a management perspective, however, this process of keeping the affected homeowners informed and educated about the project is recommended and will be encouraged in future similar dam removals around southern New Jersey.

Acknowledgements

This research was funded in part by a 319(h) Nonpoint Source Pollution Control and Management Implementation Grant from the New Jersey Department of Environmental Protection.

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