Memo

Date: February 28, 2016
To: Malcolm Duncan Jr. Mayor of Waco
Waco City Council
From: STUDENTS
Baylor University
Subject: Recommendation for Brazos River Cleanup Project

Attached is a report on our study of possible solutions to pollution along the Waco stretch of the Brazos River. The research is in line with our original proposal of finding an effective solution to combat the litter or chemical contaminants of the River.

The research we conducted comes from looking into examples of our solutions that had been used in other areas to improve water quality. This was found through online research databases and the Baylor Library. The information found was collected and compared to choose the option our group believed would be the greatest benefit to Waco.

Our research focused on two main areas each divided into two subgroups. One main area was the cleanup of visible litter along the river through either group organization or a piece of technology to help collect the litter with little manpower. The other area was the cleanup of chemical pollution that could be removed through either laws that limit the amount of contaminants dumped into the water or dredging the river.

There were four criteria that our research was based on and they were cost, effectiveness, and effect on wildlife and populations. Cost is an obvious choice because the amount of money available can be the difference between an extremely advanced solution and a more classical one. Effectiveness again is important since we wanted to find the most effective solution we could without sacrificing anything. Finally, the effect on wildlife must be considered because some option may create more harm to the ecosystem rather than saving it.

After comparing our options against these criteria we decided on organizing volunteer groups to clean up the river. This option was extremely cheap and extremely effective. The main cost is time and equipment for the volunteers. The effectiveness is purely based on the effort of the volunteer groups and the groups we had in mind are all hard working and care for Waco. The effect on wildlife is minimal since the garbage collected is from the water's surface and fish will not be caught up in the collection methods.

We strongly believe this method would clean up Waco's stretch of the Brazos River. With Waco's recent growth a cleaner river would be something every Wacoan could be proud of and enjoy, from the beautiful Cameron Park down to the grand McLane Stadium.

Addressing Pollution in the Brazos River:
A Recommendation Report

Prepared for: Waco City Council

Prepared by: STUDENTS

March 4, 2016

Abstract

In the month of February 2016, we decided to explore options by which we may improve the conditions of the Brazos River, particularly the segment of the river running through Waco, Texas. The Brazos River, which bisects Waco, is chemically polluted by pharmaceutical drugs, and littered with trash and debris so badly, that it requires immediate action in order to improve the ecosystem for the animals inhabiting the water, and the overall water quality for Waco residents. In order to quickly and permanently solve these problems, we conducted thorough secondary research and developed a strategic plan. The river will be cleaned of debris and trash through a coordinated effort of local volunteer organizations, the Brazos River Authority, and new technologies. The Brazos River is contaminated and needs to be cleaned, in order to save the health of the animals, allow people to use the river for drinking water, and improve the Waco economy by bringing more people to the area in the summer.

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Executive Summary

In the month of February 2016, we decided to explore options by which we may improve the conditions of the Brazos River, particularly the segment of the river running through Waco, Texas.

A walk down the bank of the Brazos River is all it takes to realize that the river is extremely polluted and requires immediate attention. Loose bottles, cups, bags, and other natural debris from upstream litter the banks of the river, creating an unsightly environment for residents or visitors, as well as a dangerous environment for the wildlife that inhabits the river. In addition to the trash pollution, large amounts of chemical runoff from upstream farms and plants, and pharmaceutical pollution from the dumping of drugs contaminate the Brazos, posing their own risk towards the health of the Waco community. Improving the state of this major body of water running through the heart of our city would improve environmental, health, and economic aspects of the Waco area.

In our study, we decided to explore both the physical and chemical problems plaguing the Brazos River, and then explored two solutions for each issue. To evaluate the feasibility of our solutions, we used four main criteria: cost, effectiveness, and effect on wildlife and populations. We explored two physical debris cleanup options, one of which included working alongside the Brazos River Authority and utilizing volunteer organizations to clear the river of the trash and other debris, while the other was somewhat more involved using a trash wheel to slowly clear the river of debris. While the trash wheel requires no physical labor or power, the machine itself is quite expensive and built more for a standing water situation than for a flowing river like the Brazos. Furthermore, we explored chemical cleanup options such as dredging which is an expensive and invasive process that has to be repeated every few years in order to remain effective. Dredging also does not address the ongoing issue of pharmaceutical and chemical waste entering the river from farms and plants upstream. The prevention of pharmaceutical wastes entering the river through drug recycling and collection programs was also investigated. However, based on our criteria, the physical cleanup option using volunteer efforts and the resources of the Brazos River Authority would be the most effective solution for the existing problem plaguing the Brazos River. Relative to the large machinery proposed by some of the other options, this option is relatively inexpensive. Additionally, this option is effective both in improving the aesthetic appearance of the river and the safety of the river for those using it recreationally. Finally, cleaning the river of trash would decrease the risks posed to the wildlife swimming in the river.

Based on our research and criteria, we recommend that the City of Waco, with the help of the Brazos River Authority, proceed with cleanup of the Brazos River's pollution by the means of physical trash and debris pickup with minor prevention techniques.

Introduction

In the month of February 2016, we decided to explore options by which we may improve the conditions of the Brazos River, particularly the segment of the river running through Waco, Texas. As members of the Waco City Council and residents of our city, we are sure you are aware of the trash in the Brazos River, but not only is our river heavily littered, it is also badly polluted by pharmaceutical drugs. The consequences extend far beyond the immediate problem of a dirty river. The trash and debris that are prevalent in the waterway are unsightly for both the Waco community and visitors. People are unable to enjoy the river fully as a source of recreation, having to navigate around substantial debris. Furthermore, chemical pollution, particularly in the form of discarded pharmaceuticals, has been shown to affect the life cycles and behaviors of wildlife, which includes fish, ducks and other aquatic animals. These chemical pollutants also have the potential to harm the people who come into direct contact with the water regularly. We need to improve the ecosystem for the organisms inhabiting the water, as well as improve overall water quality for Waco residents.

In order to quickly and permanently solve these problems, we conducted thorough secondary research on both chemical and trash removal methods that would potentially clean the Brazos River in Waco. We then chose the best option and devised four separate methods tailored specifically to cleanup in the Waco area. Each of these options addresses either debris cleanup or chemical cleanup of the river.

The first option we considered is physical cleanup of the river. This involves collaborating with the Brazos River Authority and organizing a group of volunteers to pick up trash and debris, which is defined as larger objects such as tree trunks that impede the water way. We would concentrate our efforts along the side of the river and in the river itself. In particular, this method uses volunteered man power and a float boom, which is an easily movable contraption that collects trash in waterways. This method is advantageous for its low cost and minimal negative effects on wildlife. It also has the potential to increase sense of community among the Waco population, and would be significantly effective.

As a second option, we researched the “Trash Wheel”. This method is based off of a hydro and solar powered water wheel in Baltimore. This trash wheel would lift trash from the water and dispose of it on a floating barge. The trash would then be transported to a landfill. However, burning the trash to create energy is another option. The positives of this method include high effectiveness, a potential tourist attraction, and no negative effects on the wildlife or Waco community. Its negatives include high costs, although it relieves the need for a constant cleaning crew and these costs might be mitigated by private investors.

Thirdly, we researched methods to prevent pharmaceutical pollution, which is the presence of chemicals in the waterway derived from drugs that were improperly disposed of. In particular, we explored the possibility of setting up disposal sites for these unused pharmaceuticals. These could be strategically located in pharmacies, hospitals, and schools. The drugs would then be collected biweekly and properly disposed of. At the same time, we would launch programs to educate the community on proper drug disposal. This option is relatively low in cost and high in efficiency. It would also have only positive effects on the Waco community and affected

wildlife. However, this solution unfortunately does not solve the problem of pharmaceuticals and other chemicals currently in the waterway.

Finally, we explored dredging as an option to physically remove pharmaceuticals and other chemicals in the waterway. This would entail hiring a dredging contractor and launching an extended project to remove sediments in highly affected areas of the river. Sediments would then need to be processed for chemical removal and then possibly sold for reuse. This solution would be highly effective in cleaning the river chemically but would not prevent future chemical pollution. It would also be highly costly, with comparatively little monetary return. It would have positive long term effects on the community and on the wildlife, but in the short term would disrupt and likely distress the wildlife and would cause unsightliness and inconveniences for the Waco community.

After we researched these options, we judged them according to criteria we deemed necessary for success. Firstly, we evaluated the monetary cost. We recognize that the Waco City Council funds are limited, and the cost of carrying out each project must be weighed against the benefits. Our second criterion was effectiveness in cleaning the river. Of course, the solutions that will more effectively solve the problems will be more valuable to us. And finally, we evaluated the respective impacts on the wildlife and community as part of our criteria.

Each of these criteria were evaluated separately for each option. We then compared the options to determine which would be the best overall. We concluded that the physical removal of trash and debris using volunteer groups would be best.

We strongly recommend that we use volunteer manpower to clean the Brazos River. This solution has the lowest projected cost by far. Additionally, since we are concentrating on only the Waco portion of the river, this solution could easily be just as effective as the more drastic options such as the trash wheel and the dredging project. Finally, it confers only positive benefits on the public and the wildlife, whereas other options might call for methods that have short term disruptive effects on the wildlife or community. While it may not be a permanent solution, it is a project easily repeated. This option has the additional benefit of bringing the Waco community together in pursuing a common goal.

In the following sections we provide an in depth discussion of our research and proposed solutions. We also explain our recommendation more fully.

Option 1: Physical River Cleanup

Summary and Problem as it Pertains to Option
The first option we have discussed to clean up the Brazos River is through an organized volunteer party, in unison with the Brazos River Authority, to physically pick up trash and debris along the bank of the river, as well as floating downstream. Through the implementation of trash programs and educational signs along the river, the city will be able to keep the river clean in the long term.

The main aspect of the river that needs attention and action is debris and trash in the water. If you were to just take a stroll across the pedestrian bridge to McLane stadium, and look to your left or right, you will notice heavy clumps of trash along the shore and debris such as tree branches or tires floating along. It is an evident fact that the Brazos River is not clean. The issue of trash in the Brazos River, especially in Waco, is a prevalent one because the strong currents bring trash from upstream, only to be clogged by the spillway. The Waco Tribune has brought this issue to light on many different occasions citing piles of "Styrofoam, aerosol cans and plastic" (Messer). It is hard to publish facts about metric tons of trash in the Brazos River, as it is an ever-changing number because some of the trash is consistently pushed downstream. Although there is not a set statistic, there is hard evidence that the Brazos River is unclean and in need of a solution. The Waco dam, which stops the Brazos River and creates Lake Waco, is cluttered with tree branches, twigs, and debris, which subsequently catches trash within the branches. The Waco Tribune is one of the most prominent new sources to cover the environment in Waco, specifically the Brazos River. The Waco Tribune has published multiple articles, updating Waco residents, on the status of the Brazos River. The area near the Waco dam has been described as a total mess, with debris including things like "a picnic table, ice coolers and thousands of plastic bottles" (Smith). The status of the Brazos River is in immediate need of attention and effective action. This issue, although daunting, we believe can be quickly fixed in the short term, and slowly in the long term.

Description of Solution
In order to clean up the Brazos River, the first action that will be implemented is multiple clean up parties of volunteer groups that will work in junction with the Brazos River Authority. Through a series of advertisements throughout Waco high schools and student life at Baylor University, we will synthesize multiple groups to work along the banks of the Brazos for four consecutive Saturdays, in one month's time. The techniques used in the process will be relatively simple. Volunteers will wear boots or waders, life jackets, and gloves, and walk along both sides of the river, using rakes and nets, to pick up trash. Alongside them a separate individual will have a trash bag, to take the trash that the person in the water has picked up. Behind them an official in a Brazos River Authority Boat will float behind them with nets, and pick up things floating in the center of the river. Since the river is dangerous, the official will also be there to aid and assist anyone if anything bad were to occur. This method of pickup can be easily adapted to allow for people to use canoes, kayaks, or paddleboards to pick up trash along the river. After an intense volunteer cleanup, to remove all of the visible trash from the river, we plan on installing a floating boom to trap the large debris, such as tree branches, tires, and anything else that is blocking the damn. The float boom will trap all the debris in a floating net, which will then be hoisted out by a crane. The float boom is reusable and will allow for the alleviation of

debris in the future, to prevent trash from being clogged in the Waco section of the Brazos River (National River Cleanup Organizer's Handbook).

Cost

The cost of this method is relatively cheap. All the labor is free except for the Brazos River Authority. However, their labor cost is part of the state parks department, and shouldn't directly impact the city's budget, when cleaning up the river. The floating boom is sturdy, reusable, and cheap, and is an investment that will keep the Brazos River free flowing and clear of debris for years. Making the Brazos cleaner will directly cause an influx in business to the Baylor marina, and surrounding amenities or activities such as "sailgating." The cleanliness of the Brazos River, will directly affect how Waco is viewed as a city. The Brazos River is crossed by hundreds of thousands of people each day, and if it is clean, people will want to stop as they travel onwards to Dallas or Austin, because they will see Waco as a clean destination. A clean Brazos River is a small investment that will pay large dividends, positively impacting the Waco economy.

Effectiveness and Effect on Wildlife and Human Population

At the end of this two-step method the river will be visibly cleaner, as well as chemically cleaner for the animals, because there will be far less plastics and non-biodegradables in the water. The impact that this method will have on the animals is relatively harmless, because the boom has a wide spaced net, focused on only capturing large objects. Post cleanup, the river water will be returned to a more natural state, allowing the animals to live and thrive in a cleaner ecosystem, and avoid the dangers of man-made materials. Not only will the animals benefit from a cleaner river, but humans will too. Lake Waco, the main source for water in Waco, was created by a dam that block up the Brazos River. If the Brazos River is cleaner, Lake Waco will be cleaner and ultimately Waco water will be cleaner.

Conclusion

This method discussed to clean up the Brazos River will be safe and effective. The manpower is free, as it will all be volunteer work, the floating boom is a relatively cheap device, and can be used hundreds of times. All work will be done safely, and all proper precautions will be taken by the Brazos River Authority, as well as all parties involved. To prevent future trash in the river we will implement an advertising campaign about littering, possibly impose a larger fine on littering, and place more trashcans along the rivers, for whomever may need them. Overall this issue is urgent, but can be solved by this method to physically clean up the river.

Option 2: The Trash Wheel

Summary and Problem as it Pertains to Option
This option is based off research on a current and solar powered water wheel that is being used in Baltimore. It's an effective method for harnessing the power of the water current and sun to clear from the top of the river. This is a long term effective solution for the trash and debris problem in the Brazos River.

Description of Solution
The technology to clean water has been on the rise recently with all the interest in preserving our environment and clean water sources. The Trash Wheel, located in Baltimore's harbor "receives power from the Jones Falls river's current near the harbor, which turns the wheel and lifts trash from the water into a dumpster barge" (Baker). The wheel is also equipped with a large solar panel on the front to provide some extra power to drive the wheel.

The advantage of this system is that there is little need for attention other than any maintenance and towing away the dumpster barge and replacing it. The trash is currently being taken and dumped in a landfill but there have been talks of using the trash to burn and create energy for four-hundred homes per ton of trash ("Tons of trash collected").

The current Trash Wheel in Baltimore is a sort of tourist attraction along the waterfront and it is no eye sore like some other trash collectors. Therefore, placing it anywhere along the Brazos would work. It would probably be most effective in an area where the most trash is and could possibly a similar attraction located either further downstream or upstream from McLane Stadium. The Trash Wheel even has its own live stream where you can watch it work any day.

Cost
The first wheel cost about eight-hundred-thousand dollars which is certainly a heavy sum. However, it was funded by the Maryland Port Administration and Constellation Energy ("Tons of trash collected"). Finding similar groups who could help fund the project here in Waco should not be hard with the recent growth of the city. An energy company such as TXU could benefit from investing in the project as they could provide more energy to customers through burning the excess trash.

The wheel could easily make the money back from the cost to purchase it by eliminating the need for physical cleanup crews as well as providing back to the community. The Trash Wheel is also a permanent installation that runs constantly so there's no need to replace it. The one in Baltimore has had steady operation for the last three years despite rain or shine and will continue to do so with the simple routine maintenance.

Effectiveness and Effect on Wildlife and Community
The Trash Wheel has some impressive stats. According to the Baltimore Waterfront website the wheel has removed about three-hundred and eighty-four tons of trash since it started in May of 2014 (Waterfront Partnership). Included in this are plastic bottles, polystyrene containers, cigarette butts, glass bottles, grocery bags, and chip bags. This trash is typical in communities and floating garbage is generally the biggest eyesore on the river. The Trash Wheel manages to

keep Baltimore's harbor clean of about three hundred tons of trash a year and the manager, Bill Flohr, claims the wheel is a time saver and collects 95% of what was normally done by hand.

The Trash wheel has only positive effects on the surrounding wildlife. It is designed so only floating debris is collected and pushed along the conveyor belt. The only fish that would ever be dumped away with would be dead fish that had surfaced. Fish may be caught in the wheel itself but quickly dumped back out as it comes back around. Keeping the trash out of the water benefits wildlife and prevents endangering the delicate ecosystem of the marine life. Community also benefits from the Trash Wheel. The cleanup of trash removes the eyesore from the waterfront making a nicer recreational destination. It creates an interesting attraction to visit and watch as the innovative technology makes the water cleaner and safer while being completely green.

Conclusion

A Trash Wheel like the one found in Baltimore would be a great addition to Waco's waterfront. The Brazos is such a strong and beautiful river and should be enjoyed free of debris that tarnish the view. Waco is growing fast and a great way to create a better experience for tourist and Wacoans alike is through creating a better-looking city to come and enjoy. Imagine a clean river flowing through the Cameron Park down past McLane Stadium and the further down to the Lake Brazos dam. A clean river can be enjoyed by all and betters our community and wildlife.

Option 3: Pharmaceutical Pollution Prevention

Summary and Problem as it Pertains to Option
This option addresses the need for and proposes a plan for the prevention of chemical pollution, particularly drug pollution, of the Brazos River.

The Texas waterways are "the fourth worst in the nation" (Metzger) when it comes to water pollution due to the 14.6 million pounds of toxic chemicals that are dumped into the rivers and lakes every year (Metzger). Many of these toxins are cancer-causing chemicals or pharmaceutical wastes, which can be detrimental to both the wildlife inhabiting and people using the waters. These pharmaceuticals are either dumped into the toilet or excreted in human waste, which allows them to enter the water stream because sewer plants have no regulations that require them to remove such chemicals in their treatment process (Smith). "The risks and effects of these substances in these concentrations in the environment have not been determined yet. However, this issue continues to be viewed with concern due to some of the properties that many pharmaceuticals have: biological activity, lipophilic nature and resistance to biodegradation" (Gualtero 8). This means that many of the chemical influences of these drugs are unknown, especially when it comes to the breakdown of these chemicals in the body of organisms and the environment. This is a frightening notion because so many of these chemicals are being dumped, yet no substantial research exists to explore the possibly detrimental effects of pharmaceutical waste on the environment, so no urgency exists towards creating a solution to this accumulating issue.

Ideally, when a patient is prescribed or purchases a drug, he or she will finish the entire prescription or eventually ingest the contents of the package they purchase. However, more often than not, this is not the case, especially with drugs such as ibuprofen, which can be purchased in large quantities. Alternatively, patients may die or be noncompliant with their therapy, leaving leftover drugs that must be disposed of (Gualtero 13). The unused portion of the drugs is usually either thrown away or flushed down the toilet where it eventually reaches bodies of water in the surrounding area because the water plants do not filter out these chemicals during the treatment process. According to a survey cited by Gualtero, "54% [of people] disposed of medications in the trash, 35.4% flushed drugs down the toilet or sink" (13). In yet another survey referenced by Gualtero, 46% of people said they flushed their unused pharmaceuticals down the toilet (13).

Description of Solution
In order to prevent this pollution of the Brazos River, we have devised a proposition that creates proper drug disposal options for the Waco community. Because addressing the incorrect processing of the chemicals once they reach treatment plants would be a much more costly and elaborate solution, preventing the incorrect disposal of leftover drugs is a less complex, but relatively accomplishable option (American Rivers). We propose that disposal sites be set up in local pharmacies, hospitals, and even schools, where people can take their unused pharmaceuticals and dispose of them in a safe place from which they can be collected and properly disposed of. Additionally, the public should be educated about the proper disposal of medication upon purchasing any kind of pharmaceutical to ensure that they are aware of the importance of correct disposal.

The disposal stations would likely be containers similar to the needle disposal containers in bathrooms and doctor offices, but possibly a little larger in order to accommodate more drugs. Each facility would then have larger containers where the smaller containers could be emptied as they filled up. Then, biweekly or monthly a truck from an incineration plant could come by and pick up the containers full of medicine, taking the prescription bottles to recycling and the pills themselves to be incinerated and properly disposed of.

Cost

The costs associated with this option would include supplying each establishment with the correct collection containers and subsequently shipping out the collected drugs to the incineration plant. Compared to mass chemical cleanup efforts in the rivers or water treatment plants, this solution would be much more cost-effective; additionally, incinerating the drugs is the correct way to ensure that they do not end up in the waterways. Assuming people participate as expected, this solution could make a large impact on the water quality of the Brazos River.

Effectiveness and Effect on Wildlife and Human Population

Though little research has been done on the effect of these drugs on inhabitants and consumers of polluted water, as mentioned before, "fish and aquatic species appear to be the most vulnerable. Male fish in the Potomac River near Washington, DC have been found with male and female sex organs, a mutation thought to be caused by pharmaceutical compounds" (American Rivers 2). With wildlife and people in mind, prevention may a better option to consider than aggressive chemical treatment because though the chemical counteraction may effectively clean up the pollution in the river, its effects may be even worse on the organisms that live in and use the Brazos regularly. Needless to say, prevention of this pollution is the best way to ensure that the waterways of Texas, particularly the Brazos River, are less and less polluted by pharmaceutical products.

Conclusion

Preventing the pollution of the Brazos would be a viable option because it would be able to produce a solution in the long term. However, it would take a few years for noticeable effects to occur, because the existing pollution in the form of trash and chemicals would remain. This option is definitely one to consider despite the speed with which it would help to clean the river because proper disposal of drugs would positively impact all parties using the water supply today and in the future.

Solution 4: Dredging to Physically Remove Pharmaceuticals

Summary and Problem as it Pertains to Option
Chemical pollutants in rivers become a significant issue when they have a greater density than water. These chemicals will settle to the bottom of the river and mingle with the sediment. They are adsorbed into the river and affect the resident fish or other organisms, which will often come into direct contact with this sediment or even eat it. Furthermore, this sediment may be released back into the water periodically ("Sediment Quality Indicators"). Given this problem, one of the best ways to purify the river of chemical pollutants including pharmaceuticals is to remove affected sediment in a process called dredging.

After conducting thorough secondary research, we have outlined what we believe to be the most effective methods to undertake a dredging project in the Brazos River. We provide a description of dredging and the basics of these methods below.

Description of Solution
Dredging is the physical removal of sediments belonging to a body of water. There are many different kinds of dredging, but the one that best fits our goals and needs would be Clamshell Dredging. In clamshell dredging, a crane barge with a clamshell bucket is used on the river. This bucket physically grabs sediment of the bottom of the river and deposits it on the barge. The barge is then towed to shore, where the excavated material is transferred to a truck that can carry it to be processed elsewhere ("An Owner's Guide"). After being processed this sediment can serve many other purposes ("Beneficial Use").

To address the problem in the Waco area, we would need to start by to testing sediments in certain areas in the river and address the areas with the worst pollution. This could be done in several ways. We could work with the Brazos River Authority, which performs tests on river quality regularly ("Water Quality"). We could also work with ecology research groups at Baylor University willing to collaborate with us for data collection. After data is obtained we would set a threshold concentration and target all areas containing sediment above those concentrations.

Once we have determined the areas necessary to dredge, a dredging contractor would be hired. In "An Owner's Guide to Managing a Dredging Project", Dredge America provides a list of ten questions to consider when hiring a dredging contractor, including "Does the contractor have several years of hydraulic dredging experience on similar types of projects?" and "Does the contractor have a good safety record and policies in place for accident prevention?". These and other resources can be used to hire a competent and effective dredging contractor. This dredging contractor will handle the process of actual dredging and transport of sediment to a processor.

Once the sediment has been processed and purified of chemicals, it is available to be used for a variety of reasons, including land creation and construction fill, beach nourishment, and habitat restoration ("Beneficial Use"). Because of its many uses, we would be able to sell to a variety of markets willing to buy the dredged material.

Cost
The largest deterrent for this particular solution is that it would be particularly expensive. While testing for concentrations might cost little to none to the extent that it would be done with Baylor researchers or the Brazos River Authority, an outside party might need to be hired in the case of a need for more thorough data analysis.

Further, hiring a dredging contractor would cost a great deal of money. Contractors must be compensated for permits and surveys performed on the area. Further, a contractor would need to be paid for mobilization, or movement of sediment off site. And finally, of course, we would need to pay a dredging contractor a flat fee for each cubic yard of sediment removed ("An Owner's Guide"). When compared to projects of a similar size, it can be estimated that we would need to extract at most 2000 cubic yards or sediment. Given that a typical rate for a small project is near $20 per cubic yard, and adjusting for permits, mobilization fees, and processing, the costs directly related to dredging could be as much as $750,000.

Selling the dredged sediment could make some of this cost up, but it wouldn't help much. At best the total net cost would be near $800,000, factoring in possible testing and other relatively small miscellaneous costs.

Effectiveness and Effect on Wildlife and Human Population
Dredging would be significantly effective in purifying the Brazos of chemical pollutants, but it still has its limits. As dredging only extracts soil and does not filter the water itself, it could not remove dissolved pollutants. However, dredging has proved extremely effective in other pollution cleanup projects. For example, efforts to dredge the Hudson River to remove PCBs have been very successful. The Environmental Protection Agency has been continuously evaluating the river and has determined that the wildlife is thriving and the river is now safe for recreation ("History of Cleanup"). The Hudson River is a model of success in chemical cleanup through dredging.

The solution of dredging would pose some significant negative impacts on the Waco community and river wildlife in the short run, but would prove ultimately beneficial in the long run. Aquatic animal behavioral patterns and ecosystems are greatly disrupted during dredging. The presence of construction equipment and the disturbance of the sediment would be a large disruptor to wildlife in the area while the project is being undertaken ("Environmental Impacts").

Furthermore, the project would affect the Waco community as well. Areas near the river would be cluttered with construction equipment. For a time, the river itself would be hindered for recreation in the areas where dredging is being carried out.

In an article considering the environmental effects of dredging, the UK Marine Special Areas of Conservation qualifies, "In considering the environmental effects of maintenance dredging and disposal, the potential benefits of these operations should not be overlooked". Despite any temporary consequences, dredging would have a long-term positive impact on the community and the Brazos River. As the Hudson example shows, chemical levels could be greatly reduced, allowing for a restoration of healthy wildlife and safe recreation for the Waco community.

Conclusion

Dredging is an attractive option for several reasons. It would be greatly effective in removing chemicals from the waterway in Waco, restoring healthy conditions to the wildlife in the area and enabling the population to use the river safely for recreation. However, it is a very costly proposition. Furthermore, it could disrupt and distress wildlife in the short run while also disturbing the shorelines.

Recommendation

After reviewing the four options proposed to clean up the Brazos River, we believe that cleaning the river using the first option, physical cleanup, is the most feasible, cost effective, and productive method. We compared the four methods to clean up the Brazos based on four main criteria: basic overview, cost, effectiveness of solution, and effect on wildlife and human population. Based on these four criteria, it became evident that choosing the physical cleanup method, would not only be cheapest, but would have the least impact on wildlife, while having the greatest positive impact on human life. Finally, we believe this method is easiest to implement city-wide and will positively impact the economic facets of Waco, in addition to the environment of Waco.

The first step we took in deciding which option would best amend the current conditions of the Brazos River, was thoroughly researching multiple viable options, both chemical and physical. After concluding our research, we came up with four solutions, two chemical cleaning solutions and two physical cleaning solutions, all of which would greatly improve the overall condition of the river. We then evaluated the four options on the criteria based on overall effectiveness, cost, and overall impact. Through this evaluation we were able to draw multiple conclusions about all four options as to why or why not we should choose a specific option, as well as ultimately choose one solution.

First, we decided against chemical cleanup in favor of trash cleanup. The two main reasons we decided against a chemical cleanup option to clean the river were cost and effectiveness. Since the Brazos River is mostly chemically polluted by pharmaceutical drugs in the water, the best way to improve the toxicity of the water is a process called dredging. This is an effective method to clean the water, however, at the cheapest it costs $800,000. In addition, it may have to be done multiple times every few years, because this option wouldn't address the release of chemicals by upstream plants or the thousands of pharmaceuticals still being flushed down the toilet. Dredging is a drastic and expensive method to improve the water quality for a short period of time, with no long-term benefits. We also believe option three would not be as effective as option one. The chemical problem of the Brazos goes beyond the scope of Waco. Not only do Waco residents dump pharmaceuticals into the system water, but upstream farms and manufacturing plants also dump chemical and toxins into the river. So although option three could effectively prevent the dumping of pharmaceuticals into water in Waco, the overall toxicity of the river would not improve because of the chemicals still polluting the water from upstream.

After deciding against options for chemical cleanup we focused on which physical cleanup method would be more effective in the short and long term. The first option for physical cleanup was through volunteer efforts, working with the Brazos River Authority to completely clear the river of all debris and trash. The second option we considered was a technological water wheel that slowly clears the river of all trash. When we evaluated these two side by side, it was clear that although the water wheel requires no labor or power it would cost far more than option one and would not clear the river of large debris. In addition, the water wheel was designed to operate in a harbor or relatively closed body of water, and since the Brazos River is constantly moving, the water wheel would not be able to operate at full efficiency. The method of cleanup

through physical pickup, although tedious and slow, is one of the most common methods used to clean up rivers, because it is cheap effective, and lasting.

We believe that choosing to clean the Brazos River through the implementation of volunteer groups and the use of a floating boom is the best option. The river can be kept clean through the implementation of park signs and more trashcans along the river. With the installation of park signs displaying the effects of littering and the penalty, with a trashcan right next to them, people will be less likely to openly litter. Most of the trash is caught on the Waco dam because the dam is clogged with large debris. However, our option will clear this large amount of debris out, through the use of the floating boom, allowing small objects to flow freely down the river, preventing the backup of trash in the Waco section of the Brazos River. The floating boom is sturdy and reusable which will allow the city to alleviate any other jams caused by debris in the future.

The Brazos River is home to many tourist attractions such as the Waco suspension bridge and McLane Stadium, and is also intersected by I-35, one of the busiest freeways in Texas. That being said, we believe that clearing the river of trash and debris will contribute to a greater use of the river for leisure, as well as more positive connotations associated with Waco and the Brazos River. If the Brazos River is clean it will positively reflect Waco's care for the environment and will lead to influx of people stopping in town or visiting, which will ultimately improve the Waco economy. With the trash and debris gone from the river, the chemical levels of the river will slightly improve, and the wildlife within the Brazos River ecosystem will be in a far more natural environment and be clear from the dangers presented by plastics and synthetics being in the water. In addition, with a cleaner river, the overall cleanliness of water available to Waco residents will be improved.

Overall, the decision to clean the Brazos River using option one is a smart, cost-effective decision that will pay great dividends to the Waco environment and community. This decision is cheap, utilizing free labor from Baylor University and volunteer organizations, and a reusable floating boom. Not only will it improve the cleanliness of the water for the animals and Waco residents, but it will improve the Waco economy and allow for more recreational use of the Brazos River. This option is easily implemented, and repeated, and will yield long term results within a year.

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