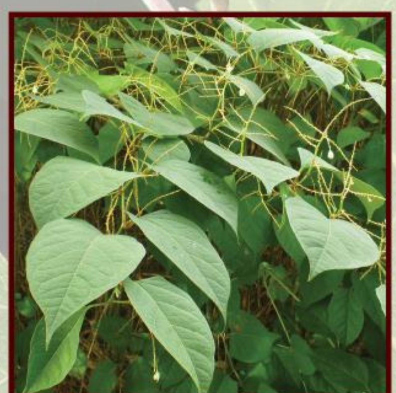
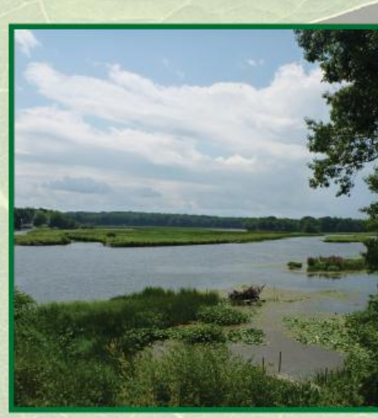
Managing Japanese Knotweed (*Polygonum cuspidatum*) in the Salmon River and Salmon River Estuary

Assessment and Feasibility Analysis

Prepared by Gregory S. Chapman and Robert K. Williams
with contributions from Michael McHale





November 2012

St. Lawrence - Eastern Lake Ontario
Partnership for Regional Invasive Species Management

About SLELO – PRISM

The **St. Lawrence Eastern Lake Ontario Partnership for Regional Invasive Species Management** is one of eight partnerships in New York State, encompassing St. Lawrence, Jefferson, Oneida, Lewis and Oswego counties outside of the Adirondack Park.

Our mission is to protect native habitats, biodiversity, natural areas, parks and refuges, freshwater resources, farmland and open space by using a collaborative and integrated approach to invasive species management. The emphasis of these activities will be on prevention, early detection, rapid response and education.

Copies of this report can be obtained
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Hosted By

The Central & Western New York Chapter of The Nature Conservancy

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Table of Contents

Managing Japanese Knotweed (*Polygonum cuspidatum)*
In the Salmon River and Salmon River Estuary

Assessment and Feasibility Analysis

Abstract

The Salmon River, located along the eastern shore of Lake Ontario, is a valuable cultural and natural resource worthy of protection from the habitat-altering impacts of invasive species. As a cultural resource, the Salmon River is a multi-million dollar fishery hosting in excess of 100,000 angler visitors annually. Angling enthusiasts travel from numerous regions across the United States and Canada, as well as from throughout the world, to fish the river. Many local businesses thrive as a result of this cultural resource.

This 17-mile river system is rich in habitat and diversity and provides, both in the upstream reaches and within the estuary, spawning and nursery grounds for pacific salmon (Chinook, Coho and Steelhead) and the native Atlantic salmon. The estuary provides shorebird nesting sites for species such as the Black Tern and the Least Bittern.

The increasing dominance of Japanese knotweed, an aggressive invasive plant present within the Salmon River corridor, has the potential to negatively impact the economic and ecological values of the Salmon River and Salmon River Estuary. Dense stands along the upstream portion of the Salmon River interfere with angler access, making some areas of the river less attractive to fishermen. Large-scale alteration of the plant structure within the estuary could have direct impacts on shorebirds and other organisms that rely on the unique composition of emergent and riparian plant communities for shelter, nesting materials and food.

Due to the widespread nature of existing Japanese knotweed populations on the river, eradication of knotweed is not a realistic goal. However, control and management options do exist to aid in suppression of Japanese knotweed, even on a river-wide scale. Our recommendation involves suppression of Japanese knotweed over the course of a minimum of three years using a stem injection technique as the primary control strategy. This suppression action should be only one part of a larger Salmon River Initiative that also includes activities aimed at native plant restoration as well as education and outreach.

Goal - The purpose of this document is to evaluate what measures (if any) should be taken to protect the ecological and cultural integrity of the Salmon River and its estuary.

Introduction

The Salmon River in Oswego County, New York represents an important natural resource within the St. Lawrence - Eastern Lake Ontario Partnership for Regional Invasive Species (SLELO-PRISM) region. The importance of sport fishing along the lower Salmon River, particularly during the annual fall salmon season, cannot be overstated in terms of its impact on the local economy. In addition, portions of the lower Salmon River provide critical habitat for terrestrial and aquatic organisms, some of which are of special concern within New York State.

The presence of Japanese knotweed within the river system is not new, and populations of Japanese knotweed have been noted in the region since at least the late 1980s and were likely present before then. However, the increasing density and distribution of this invasive plant could severely impact the recreational and ecological value of the lower river if it is allowed to continue its spread without restraint. This document seeks to outline the ecological, critical habitat and recreational values of the Salmon River and Salmon River Estuary, identify some of the ways which the unchecked spread of Japanese knotweed may alter the character and value of this landscape, and determine the feasibility and options available for enacting control of this invader on the river.

Impacts, distribution and control of Japanese knotweed within two major portions of the lower river will be discussed separately: The Salmon River Freshwater Estuary, located near the mouth of the Salmon River as it meets Lake Ontario, and the upstream portion of the Salmon River, the roughly 17-mile stretch of river between the Lighthouse Hill Dam and the estuary. Although both are part of the same continuous river, these two areas differ greatly in environmental values, human use patterns, Japanese knotweed impacts and knotweed distribution.

The Salmon River Freshwater Estuary

Location and Site Description

The Salmon River Freshwater Estuary (Figure 1) is an approximately 270-acre area of emergent marshes, riverine wetlands and shrub swamps at the mouth of the Salmon River in the Town of Richland, Oswego County, New York. As described in the Salmon River Watershed Natural Resources Assessment (McGee 2008), the Salmon River estuary is defined as that area of the lower Salmon River that is influenced by Lake Ontario's water levels. This includes the area between the barrier dunes of Lake Ontario to the west, and the last riffle of the Salmon River to the east, which is found approximately 1200 feet upstream of the New York State Route 3 bridge (McGee 2008).

Figure 1: View of the Salmon River Freshwater Estuary, looking west from near the Route 3 bridge. *Photo by Greg Chapman.*

The Salmon River's channels within the estuary are generally shallow, with depths ranging between 3 and 7 feet, and some portions are periodically dredged to maintain a navigable channel. The river as it passes through the estuary is braided with sandbars and beds of emergent vegetation. Comprising the estuary's 270-acre area are several wetland habitat types, and includes approximately 130 acres of riverine wetlands, 110 acres of emergent marshes, and 30 acres of woody wetlands (McGee 2008).

Land Ownership

Land ownership within the estuary is fragmented, and much of the estuary is privately owned and developed. Publicly-accessible property within the estuary includes land held by the New York State Office of Parks, Recreation and Historic Preservation (NYS-OPRHP), such as Selkirk Shores State Park and the associated Pine Grove State Boat Launch. The New York State Department of Environmental Conservation (NYS-DEC) owns and maintains a Public Fishing Access area off Route 3, which includes a parking lot and handicapped-accessible fishing platform. An island upon which a portion of the Route 3 bridge is built is owned by the New York State Department of Transportation (NYS-DOT). Most of the privately held lands within the estuary are developed with camps and residences on small plots of land.

Habitat and Ecological Importance

The Salmon River estuary contains vital habitat for both aquatic and terrestrial organisms, including some state-protected bird species.

In addition to being recognized as highly productive warm water fish habitat, the estuary also serves as an important staging area for annual fall migrations of spawning salmonids, such as Chinook salmon (*Oncorhynchus tshawytscha*), Coho salmon (*O. kisutch*), land-locked Atlantic salmon *(Salmo salar)* and brown trout (*S. trutta*). Steelhead (migratory rainbow trout – *O. mykiss*) also pass through the estuary during the fall and winter preceding their annual spawning that takes place upstream during the spring.

A variety of birds, including several state-protected marsh birds, utilize the emergent marshlands and swamps within the estuary as seasonal nesting and feeding areas. State-protected birds that have been observed nesting within the estuary include threatened species such as pied-billed grebes (*Podilymbus podiceps*) and least bitterns (*Ixobrychus exilis*), as well as the endangered black tern (*Chidonias niger*). These birds rely on the vegetation structure within the estuary for nesting cover and materials (McGee 2008).

Black terns (Figure 2) feed and nest in large shallow freshwater emergent wetlands, margins of lakes and some river edges. Black terns build nests on a floating substrate of matted vegetation, often cattail or bulrush (USFWS 2001). Black terns feed on a variety of aquatic insects, particularly dragonflies, damselflies, mayflies, and caddisflies, as well as small fishes and crustaceans (Novak 1992, Dunn and Agro 1995 as cited by USFWS 2001).

Figure 2: Black tern (*Chidonias niger*). *Photo Credit: The Nature Conservancy.*

Economic Importance and Recreational Utilization

The Salmon River estuary is a popular destination for boaters and outdoors enthusiasts. Throughout the summer months, boaters utilize the Pine Grove Boat Launch both to fish directly within the estuary, or to access nearby Lake Ontario. Canoes and kayaks are also frequently encountered within the estuary during the warm summer months.

Although the estuary is utilized by anglers targeting salmon and steelhead during their annual migrations, the general distribution of fishermen within the estuary at these times differs somewhat from those fishing upstream along the upstream portions of the Salmon River.

Compared with shoreline use along the upstream portion of the river, salmon and steelhead anglers utilize very little of the shoreline within the estuary. Most shoreline use is concentrated within the areas adjacent to the NYS-DEC Public Fishing Access parking lot and the State Route 3 Bridge. A variety of boats, both motorized and non-motorized, also utilize the estuary during the fall salmon runs. In contrast, anglers along the upstream portion of the river fish mainly from shore or standing within the river, or fish from non-motorized drift boats specifically designed to navigate river rapids.

Main Impacts of Japanese Knotweed within the Estuary

The continued spread of Japanese knotweed within the estuary has the potential to alter the plant community composition within emergent marshes and woody wetlands. This can have direct impacts on organisms that rely on the vegetative structure currently found within the estuary, including nesting shorebirds. Japanese knotweed also has the potential to impact the abundance and diversity of phytophageous (plant-feeding) insects, which may alter the overall food web structure within the estuary.

Salmon River (Upstream)

Location and Site Description

The upstream section[1] of the Salmon River is located in Oswego County, New York, and passes through the villages of Pulaski and Altmar. For the purposes of this report, the upstream section of the Salmon River is considered to be that portion of the river between the upper limit of the estuary and the Lighthouse Hill Reservoir dam, for an approximate linear distance of 17 miles. Whereas water levels within the estuary are influenced primarily by Lake Ontario, water levels in this portion of the river are determined primarily by the amount of water being discharged from the Lighthouse Hill Dam, as well as contributions from several tributary streams. Recreational utilization and land ownership trends also differentiate the upstream of the Salmon River from the estuary, and habitat types and ecological importance differ as well.

Land Ownership and Public Access

Although public fishing access is plentiful along the upstream of the Salmon River, very little of the land adjacent to the river is actually publicly owned. Anglers are permitted access to much of the river due to the presence of Public Fishing Rights (PFR) easements on private land; approximately 12 miles of PFRs are currently held on the upstream of the Salmon River. These permanent easements allow access to the public along a 33-foot wide stretch of stream bank for fishing purposes only.

Figure 3: The Salmon River, upstream of the County Route 2A bridge. *Photo by Greg Chapman.*

Some public and municipally-owned lands are found along the upstream section of the Salmon River. Several parking areas near the river are owned and maintained by NYS-DEC. Lands bordering the Salmon River as it passes near the NYS-DEC Salmon River Fish Hatchery in Altmar are owned by the NYS-DEC, however this portion of the river is restricted from public access. The Village of Pulaski owns and

[1] Above the influence of the lake which generally separates the estuary from the river.

maintains several parcels of land adjacent to the river as it passes through the village.

There is a mixture of private ownership along the upstream section of the river, and some large continuous stretches of privately-held river property are worth noting.

The Douglaston Salmon Run (DSR) is a continuous tract of privately-held land that encompasses both banks of the river downstream of Pulaski for a linear distance of approximately two miles. Access to this stretch of river is carefully restricted. Anglers wishing to fish within the DSR must pay a fee for access, and the total number of people permitted to fish within the property is limited each day.

A second significant holder of private land along the river is the Brookfield Power Company, whose land holdings relate to the river's use in generating hydroelectricity at the Lighthouse Hill Dam. PFRs have been secured along the river's upstream section within much of Brookfield Power Company's land holdings.

The remainder of private lands is a mixture of year-round residences, business properties, agricultural lands, seasonal properties, and property held by land development companies. Any PFRs formerly secured on these properties (such as on former power company property that has since been developed) remain in effect following any transfer of land ownership.

Habitat and Ecological Importance

Populations of Chinook, Coho and Atlantic salmon, steelhead and brown trout are maintained both through annual stocking and management focused on enhancing natural reproduction of these fish within the river.

Salmon and trout spend the first part of their lives in the rivers and streams that serve as their nursery grounds prior to migrating to larger bodies of water (such as Lake Ontario) to feed as adults. The habitats that salmon fries live in are large cool rivers with extensive gravely bottom headwaters. The gravel substrate found in many reaches of the Salmon River provides spawning grounds for these salmon. Salmon rely on these substrates for egg incubation and for protection once fries have hatched. Young salmon feed on a variety of organisms within their nursery streams and rivers, such as small crustaceans, aquatic insects and terrestrial insects that fall into the water (Smith 1985).

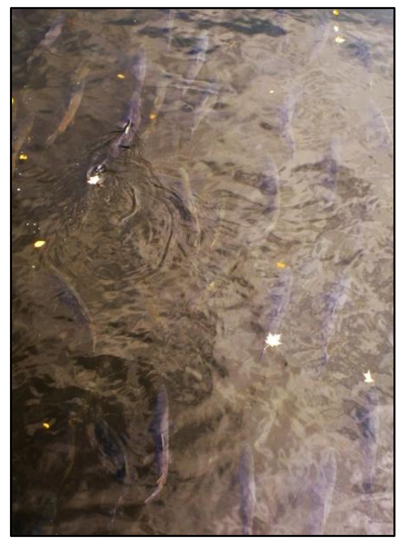


Figure 4: The dorsals of numerous salmon are visible in this picture taken from the Altmar bridge in October of 2012. *Photo by Greg Chapman.*

The Salmon River is recognized as an extremely high-quality cold water tributary fishery. Many factors contribute to its abundance of quality riparian and riverine habitat and unique fish assemblage, including the presence of the NYS-DEC Salmon River Fish Hatchery in Altmar, the habitat-based water level strategies in place for outflow management from the Lighthouse Hill hydroelectric dam, and the presence of suitable substrate for significant natural reproduction of salmonids. The Salmon River’s high-quality water originates from headwaters on the Tug Hill Plateau, and is considered one of the cleanest and most heavily-forested watersheds in New York State (Mary Penney, New York Sea Grant, personal communication, October 2012).

Economic Importance and Recreational Utilization

Fishing activities and related spending by anglers visiting the upstream section of the Salmon River are of vital importance for the local and regional economy. Fishing on the Salmon River accounted for an estimated 68% of all Lake Ontario tributary fishing within New York State during the fall of 2011 (Prindle and Bishop 2011). The regional economic impact of the Salmon River fishery was estimated to be $16

Figure 5: Anglers on the Salmon River near Altmar during the fall salmon run in early October 2012. *Photo by Rob Williams.*

million in 1996 (Focazio 2006). An angler survey conducted in 2007 estimated that on-site expenditures by Salmon River anglers totaled approximately $18.8 million during that year (Connelly and Brown 2009).

Fishing on the Salmon River during peak season draws anglers from throughout the region, as well as some from throughout the world; an estimated 63% of all anglers visiting the Salmon River in fall of 2011 were non-New York State residents (Prindle and Bishop 2011). Local businesses such as motels, restaurants, campgrounds and guide services rely heavily on the business they receive from anglers visiting the Salmon River during the fall and spring peak seasons.

Anglers targeting fall-spawning salmon and spring-spawning steelhead take full advantage of the abundance of access provided by PFRs on the Salmon River's upstream section. Many anglers choose to access the river directly from shore and by wading into the river itself; some anglers also access the river with the aid of a drift boat, a non-motorized boat specially designed to handle river rapids. Despite the extensive area that is available for fishing on the Salmon River, the large numbers of anglers who visit during peak season require that nearly all reaches of accessible river are utilized, and many significant stretches can be consistently described as crowded during peak salmon and steelhead seasons.

The annual fall salmon season, which typically peaks during the weeks of late September and early October, is when the Salmon River's upstream section hosts the greatest number of anglers. Many anglers also converge upon the river during Steelhead spawning season in March and April. Although fewer in number than during these peak seasons, some anglers also target Steelhead in the upstream section during late fall and into winter. Very few anglers utilize the river's upstream section for fishing during the summer months, however the continued stocking of land-locked Atlantic salmon and Skamania (summer-run) steelhead aims to produce a more year-round fishery on the Salmon River.

Large-scale recreational use of the Salmon River upstream section during the summer months is often limited to whitewater rafting activities that take place during scheduled high-water releases from the Lighthouse Hill Dam. These controlled releases take place five times annually between June and early September.

Japanese Knotweed Overview – Ecology, History and Impacts

Japanese Knotweed – Description and Ecology

Japanese knotweed (*Polygonum cuspidatum*, *Fallopia japonica* var. *japonica*) is a member of the buckwheat family (Polygonaceae). It is a shrub-like herbaceous plant with hollow stems that superficially resemble bamboo and can grow to 10 feet in height. Large leaves (up to 6 inches long and 4.75 inches wide) are ovate or broadly triangular in shape, have smooth margins, and are arranged alternately along the stem (Gleason and Cronquist 1995). Japanese knotweed is particularly noticeable during mid to late summer, when numerous showy, dense clusters of small white to greenish-white flowers develop from the upper leaf axils.

Japanese knotweed is a fast-growing perennial that first emerges in early spring, and persists until

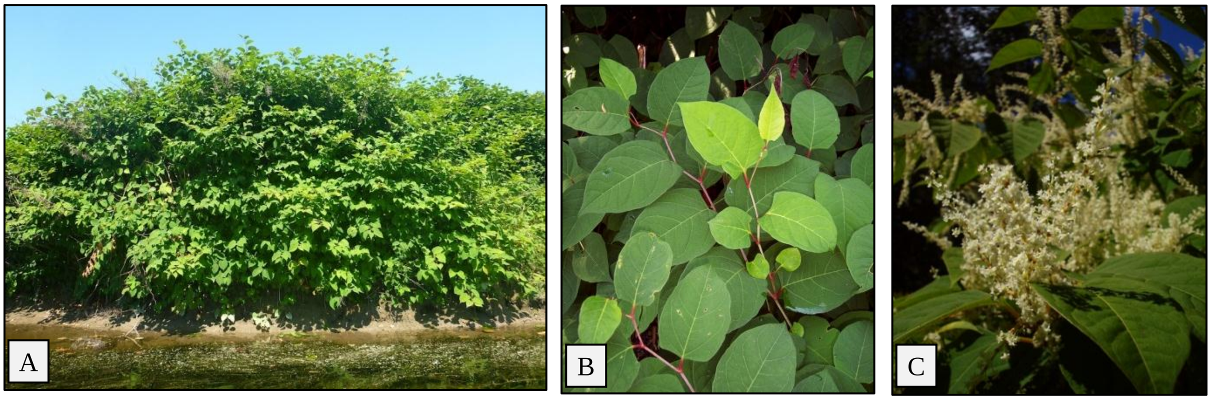


Figure 6: Habit and features of Japanese knotweed. (*All photos by Greg Chapman.*)

- **A.** Typical patch of knotweed encountered upstream of the estuary (July 2012).
- **B.** Japanese knotweed leaves (mid-August).
- **C.** Japanese knotweed flowers (early September).
- **D.** Japanese knotweed patch in full flower (early September).

above-ground portions of the plant die back following the first hard frost in the fall. Although it is able to thrive in a variety of soil and moisture conditions, it grows less vigorously in shaded areas (Seiger 1991).

Reproduction and spread of Japanese knotweed is thought to be primarily accomplished through vegetative reproduction (Seiger 1991). Very small fragments of plant material are required for regeneration; less than 5 grams of root/rhizome material are required for plants to regenerate, and stem tissue is also capable of rooting and forming new plants (Shaw and Seiger 2002). Pure strains of Japanese knotweed are not thought to be capable of producing fertile seeds. However, hybrids between Japanese and giant knotweed (*P. sachalinense*) has been shown to be capable of producing viable seeds. In addition, several reports have observed successful germination from seeds collected from wild stands of Japanese knotweed (McHugh 2006).

Once established, Japanese knotweed is capable of quickly colonizing an area with clonal stands that arise from an extensive network of rhizomes; these rhizomes are able to extend laterally from between 23 and 65 feet, and can grow to a depth of 7 feet (Soll 2004).

New populations of Japanese knotweed may be established either by intentional planting or through the natural or human-assisted spread of seeds and/or viable fragments of plants and rhizomes. Seeds and vegetative fragments may be spread by mowing or landscaping equipment used in areas infested with Japanese knotweed, or by the movement and deposition of soil containing rhizome and/or plant fragments.

Natural dispersal of Japanese knotweed can be facilitated along streambanks by high-water and flooding events. Flooding events in streams and rivers detach and transport viable plant and/or rhizome fragments, while simultaneously scouring and removing vegetation from downstream shoreline, creating disturbed areas that facilitate the initial establishment of Japanese knotweed (Seiger 1991).

Invasion History and Distribution

Japanese knotweed is native to eastern Asia, and is found naturally in Japan, Korea, China and Taiwan. It was initially introduced as an ornamental plant in the United States in the late 19th century, originally praised for its large, showy flower clusters and its hardy nature. However, by the early part of the 20th century plant catalogs already warned purchasers to avoid planting Japanese knotweed along borders and within formal gardens, due its ability to quickly spread and crowd out other plants. Instead, it was recommended for planting in out-of-the-way places such as streambanks and pond edges. Articles describing strategies for eliminating knotweed started to appear as early as 1938, and by the 1960s the plant was widely recognized as a weed to be avoided (Townsend 1997).

Japanese knotweed has also been used in the past for erosion control, however despite developing extensive rhizome networks, its ability to control erosion is thought to be poor (Soll 2004).

Currently, Japanese knotweed's North American distribution includes much of the United States and parts of Canada. It has been found as far north as Alaska, and grows as far south as Louisiana and central California. High concentrations of Japanese knotweed occurrences are found in the eastern United States and the Pacific Northwest (Shaw and Seiger 2002). Japanese knotweed is well established within the SLELO-PRISM region, and is commonly encountered growing along streambanks, in roadside ditches, near houses, and in old fields.

Impacts of Japanese Knotweed Invasions

Japanese knotweed's aggressive growth and ability to form large, dense and effectively monotypic stands has led to it being widely regarded as a very undesirable invasive plant species. Japanese knotweed has been included on a list of "100 of the World's Worst Invasive Alien Species" compiled by the International Union for the Conservation of Nature Invasive Species Specialist Group (Lowe et al. 2000).

Ecological Impacts – Japanese knotweed's ability to aggressively colonize an area through clonal growth results in greatly reduced native plant biodiversity in areas where it occurs. Knotweed is capable of creating extensive monocultures, and excludes native plants through alterations to ecosystem structure, such as shading, competition for nutrients and water, and production of deep litter mass. The reduction of native plant species diversity can potentially diminishing an area's value to wildlife, especially phytophagous (plant-feeding) and detritus-feeding insects and species that rely on them (McHugh 2006).

Figure 7: Japanese knotweed can form large, dense monotypic stands in riparian areas, such as this patch encountered upstream of the Estuary in July of 2012. *Photo by Greg Chapman.*

Knotweed is particularly problematic in riparian areas because it can survive floods and rapidly colonize scoured shores and islands. Knotweed is capable of completely dominating the plant populations found in riparian areas. This in turn can suppress the growth of riparian trees and shrubs, potentially altering habitat characteristics such as stream water temperatures. However, quantitative studies regarding the impacts of knotweed infestations on stream water quality are lacking at this time (McHugh 2006).

The effects of Japanese knotweed on streambank erosion are unclear. Although it is considered by some to contribute to streambank erosion (Soll 2004), at this time no studies have yet been completed to quantify Japanese knotweed's effects on erosion. Anecdotal reports of Japanese knotweed growing in highly eroded riparian stretches exist, particularly along the Delaware River (see Stuart 2005 for an example). However, it is not known if Japanese knotweed's presence increases erosion, or if it is rather more likely to establish itself in areas that are already more susceptible to erosion (McHugh 2006).

Recreational Impacts – Knotweed can inhibit recreational access by anglers along streambanks. Some extremely dense populations of knotweed are found along popular access points to the Salmon River. This causes spacial interruptions among anglers vying for stream space. In many areas, anglers will eventually resort to creating paths through the knotweed stands in order to access the river; this may enhance the spread of knotweed along the river as vegetative propagules are released into the river to drift downstream (see Figure 8).

Figure 8: Anglers faced with reduced river access caused by Japanese knotweed infestations will often force their way through, which can lead to dispersal of vegetative propagules. The above disturbed patch was observed near Altmar during the fall 2012 salmon run. *Photo by Rob Williams.*

Japanese Knotweed within the Salmon River Corridor

As of November 2012, no complete formal survey has been undertaken on the Salmon River to document knotweed infestations. Data for the distribution and density descriptions comes from several partial surveys completed in 2012 and an additional partial survey completed in 2011. Personal observations and discussions with persons familiar with Japanese knotweed on the Salmon River (particularly Fran Verdoliva, NYS-DEC, personal communication, 2012) have also informed the following discussion of knotweed trends on the river. For a visual representation of past Japanese knotweed survey efforts on the Salmon River, see Figure 10.

Salmon River Knotweed Distribution Trends

Knotweed is known to infest various discontinuous areas throughout the Salmon River watershed. Large populations exist near the eastern portions of both the lower and upper reservoirs of the Salmon River, both located above the Lighthouse Hill dam. With suppression being the primary goal of managing knotweed along the main stem of the Salmon River and within the estuary, treatment of these populations is not addressed within in this document. These areas may be appropriate for future management considerations to reduce potential propagule pressure from these upstream populations.

Japanese knotweed occurs in varying densities throughout the main stem and estuary of the Salmon River. However, the distribution does show some general trends that are important to consider when developing or implementing a management strategy.

A recent assessment of Japanese knotweed occurrences within the Salmon River estuary (Chapman and McHale 2012) revealed noticeable differences in the distribution of Japanese knotweed occurrences within the estuary when compared with occurrences immediately upstream of the estuary. Visual inspection of the assessment's survey map (Figure 9) shows that patches are noticeably more numerous upstream of the Route 3 bridge. Patches are particularly numerous upstream of where the eastern limit of freshwater estuary is defined to occur, which is 1200 feet upstream of the Route 3 bridge.

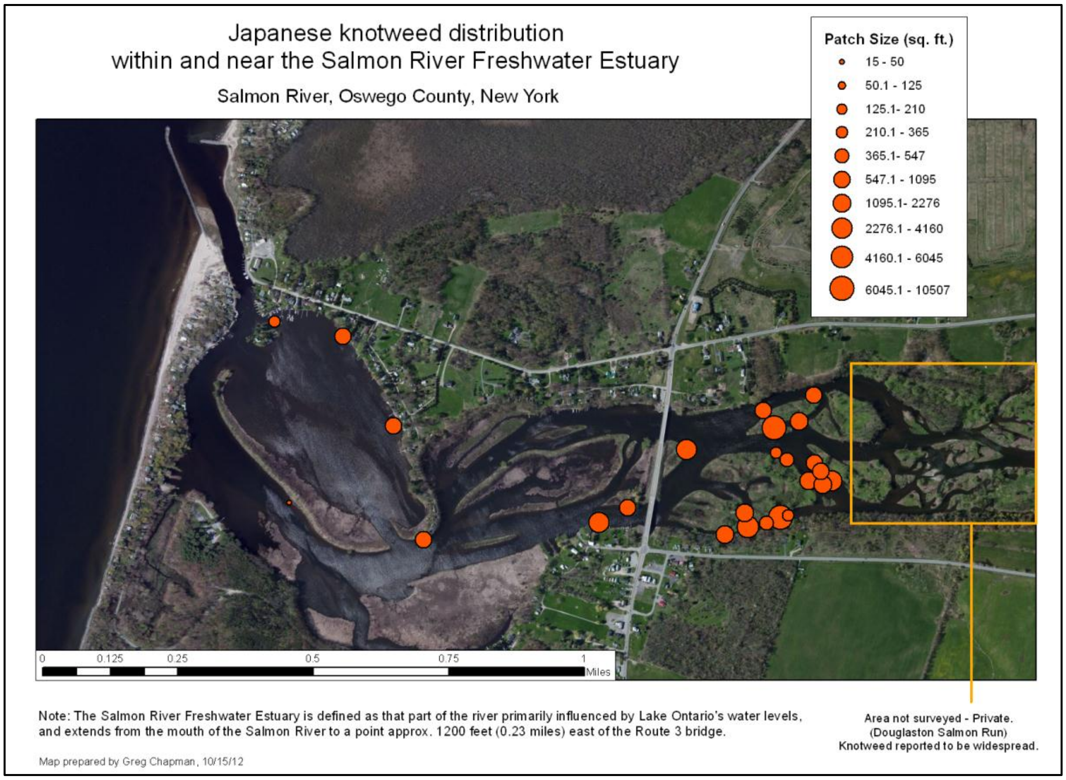


Figure 9: Japanese knotweed distribution within and near the Salmon River Freshwater Estuary. Data obtained from an assessment completed in July of 2012 (Chapman and McHale 2012).

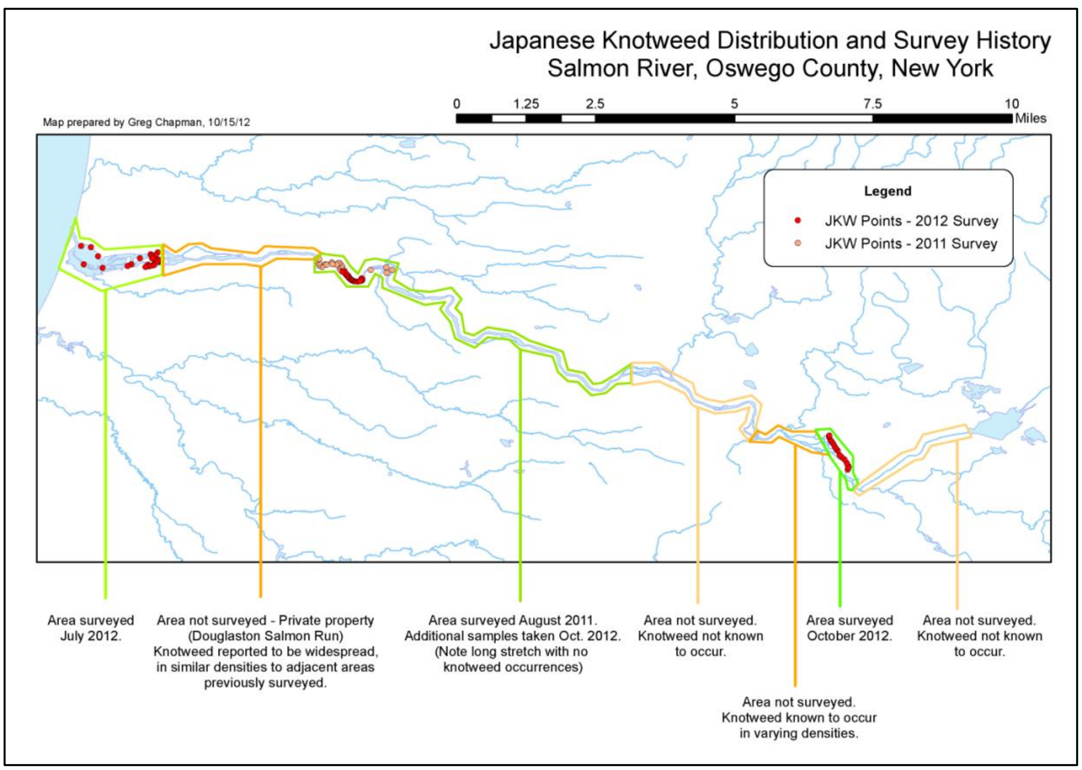


Figure 10: Japanese knotweed distribution and survey history along the Salmon River.

Upstream of the estuary, knotweed is found in abundance throughout the Douglaston Salmon Run and into the Village of Pulaski. Knotweed infestations in the immediate vicinity of the river cease at a point just upstream of the Ballpark Drift Boat Launch in Pulaski. A long stretch of river (approximately 7 miles) has been observed and reported to be free of knotweed; this stretch extends from the Ballpark to a point near what is known as the Trestle Pool. Upstream of the Trestle Pool, knotweed is once again regularly observed to a point downstream of the bridge in the Village of Altmar. No patches are known to occur between the Altmar bridge and the Lighthouse Hill Dam. See Figure 10 for a general overview of known river infestations and survey history. For a more complete discussion of previous survey efforts, refer to "Appendix I - Method for Estimating Total Japanese Knotweed Infested Area on the Salmon River".

Salmon River Knotweed Density Trends and Total Area Estimate

For sampled populations of knotweed, average Japanese knotweed patch size was observed to be greatest in the lower river (upstream of the estuary), where the average of 17 sampled patches was 2496.83 ft^2. The 8 sampled knotweed patches within the estuary had an average patch size of 1097.29 ft^2. Patches were generally much smaller along the portions of the river sampled further upstream. In Pulaski, the average size of 22 sampled patches was 448.91 ft^2, and near Altmar the average size of 16 sampled patches was 407.81 ft^2. However, within each sampled area, significant variation in patch size was observed.

For the purposes of generating control cost estimates for Salmon River knotweed, a total knotweed area estimate was needed. Results of previous surveys were used to extrapolate estimates of knotweed area along non-surveyed portions of the river where knotweed was known to occur. Using the methods described in Appendix I, the total area covered by knotweed along the Salmon River was estimated to be **271,138.35 ft^2**, or approximately **6.37 acres**. The majority of the infested area is found or estimated to occur in the lower river, upstream of the estuary. See Table 1 for a breakdown of infested area by river compartment, and refer to "Appendix I - Method for Estimating Total Japanese Knotweed Infested Area on the Salmon River" for a detailed description of the method used to generate the above estimate, as well as compartment descriptions and maps.

River Compartment	Number Of Patches	Avg. Patch Size (sq ft)	JKW Total Area (sq ft)	Compartment Total Area (acres)	Density (sq ft/acre)	Calculated Total JKW (sq ft)
Salmon River Freshwater Estuary	8	1097.29	8778.31			8778.31
Port Ontario Open Braided River	17	2496.83	42446.04	35.05	1211.01	42446.04
DSR Open Braided River				115.97		140441.29
DSR Linear River				56.06		47360.87
Pulaski Linear River	22	448.91	9876.00	11.69	844.82	9876.00
Pulaski Non-Area Samples	21					9427.11
Altmar (Non-Surveyed)				59.46		12808.73
Altmar (Surveyed)	16	407.81	6525.00	30.29	215.42	6525.00
					Estimated Total JKW	**271138.35**
						~6.37 Acres

Table 1: Data table used to estimate total Japanese knotweed area on the Salmon River. Calculated values with red backgrounds indicate that the infested area for that compartment was estimated. Refer to Appendix I for a detailed description of the method used to generate the above estimate, as well as individual compartment descriptions and maps.

Management of Japanese Knotweed – Options, Objectives and Strategies

Introduction and General Considerations

Japanese knotweed has a well-deserved reputation as a tenacious weed. Eradication of knotweed, particularly well-established and widespread infestations, is notoriously difficult; suppression of existing populations and the prevention of further spread within a management area are often more realistically attainable goals.

The ability of Japanese knotweed to regenerate or establish new plants from even very small rhizome or stem fragments should be remembered during any attempt to manage this plant, and all detached living plant material must be carefully disposed of. In addition, killing the extensive network of rhizomes developed by established knotweed patches will almost certainly require multiple years of treatment. Successful management and suppression of Japanese knotweed is a long-term undertaking. A likely approach would be to begin suppression of Japanese knotweed in the river system.

Objective No. 1 – *Suppress populations of Japanese Knotweed within the estuary portion of the system and populations within the upstream portions of the river.*

Brief Summary of Japanese Knotweed Management Strategies

A variety of techniques for the management of Japanese knotweed exist, and the most commonly used strategies are briefly listed and described here. For a comprehensive overview of strategies and case studies, refer to "A Review of Literature and Field Practices Focused on the Management and Control of Invasive Knotweed" by J. Murray McHugh (2006), available online at http://www.invasive.org/gist/moredocs/polspp02.pdf [most recently retrieved 11/6/12].

Mechanical techniques include mowing, cutting, digging and covering. These strategies are often time consuming, expensive, and limited in their efficacy, however they are sometimes required in areas where herbicide use is prohibited or is desired to be limited.

Herbicides are commonly used to suppress or eradicate knotweed, and several broad strategies exist. Foliar spray involves applying diluted herbicide directly to the leaves of the plant from a hand-held or backpack spraying device. Cut-stump management of knotweed involves cutting each stem near its base, penetrating the lower membrane with an implement such as a screwdriver, and dripping concentrated herbicide into the reservoir; all cut plant material must then be removed and properly disposed of. Stem injection utilizes a specially-designed injection gun to pierce the lower stem, after which a set amount of herbicide is delivered to the interior of the hollow stem; this technique is described in greater detail in the "Stem Injection Technique Overview and Considerations" section below.

General Suppression Strategy Recommendation – Stem Injection of Herbicide

The use of stem injection has been viewed as being most appropriate for control of Japanese knotweed on the Salmon River. This technique was selected after considering factors such as cost, reported efficacy, distribution and location of knotweed patches along the river, and the desire to minimize non-target effects and herbicide drift within these riparian areas. Although this is the general strategy selected, landscape conditions, individual patch characteristics and landowner desires may dictate the use of alternative techniques in some instances.

Stem Injection Technique Overview and Considerations

The following discussion of stem injection techniques and efficacy was greatly informed by reports of its use in watershed-scale knotweed management in Oregon (Soll et al. 2009) and from personal communication with Brendan Quirion (October 2012) of the Adirondack Park Invasive Plant Program (APIPP).

Stem injection of herbicide requires the purchase and use of a specially-designed stem injection gun, available from JK International Injection Tools (www.jkinjectiontools.com). This tool penetrates the outer stem with a needle which then delivers a measured amount of undiluted herbicide (typically less than 5 ml) to the hollow interior of the stem. An optional marking system simultaneously marks each injected stem to ensure that all stems are injected and no stems are injected multiple times. Stems that are too small to be injected (under ½ inch in diameter) will require a separate foliar application of diluted herbicide, either through wiping of leaves or spraying.

Figure 11: View of herbicide injection gun required for stem injection management of Japanese knotweed. *Photo credit: JK International Injection Tools.*

As in all herbicide strategies, proper timing of treatment is important to ensure that herbicide is transported to the root and rhizome system to effectively impact the plant's regrowth potential. For knotweed, treatment is recommended only after the plant enters its flowering stage; in New York, this is observed to take place in August and September. Treatment must be applied prior to the first frost, which rapidly kills off the above-ground portions of knotweed. For the Salmon River, special consideration for treatment timing may be required to avoid interference with anglers that arrive in significant numbers starting in early to mid-September for the fall salmon run.

Reported efficacy of this technique is high; recent control efforts in the Adirondacks using injections of 2 to 3 ml of undiluted Aquamaster® (glyphosate) per stem have a reported efficacy of 95% reduction in stem count after one year (Brendan Quirion, APIPP, personal communication, October 2012). Follow-up treatments in subsequent years will be necessary. Foliar spraying of diluted herbicide is often necessary for follow-up treatments as re-growth is typically too small to be injected. Careful application and proper selection of herbicides and surfactants will minimize non-target effects and herbicide drift during these follow-up spot treatments.

Despite the high initial efficacy, actual eradication of individual patches of knotweed remains difficult. Knotweed control efforts on the Sandy River in Oregon have noted success in eradicating many small patches; however no patch larger than 573 initial stems had been successfully eradicated, even after multiple years of various treatments. Use of glyphosate-based herbicides also led to observations of deformed (epinastic) growth in following years, and treatment of this deformed regrowth appears to be limited in its effectiveness in killing below-ground rhizomes (Soll et al. 2009). Although Soll et al. (2009) noted that the introduction of imazypyr-based herbicides reduced the prevalence of deformed regrowth, these herbicides are not currently approved for use in knotweed control in New York State (Chris Zimmerman, The Nature Conservancy Eastern New York Chapter, personal communication, October 2012).

Due to the volume of undiluted herbicide used during stem injection, particularly large patches may require special considerations to avoid introducing volumes of herbicide greater than are permitted or desirable per acre. Accessibility of individual stems may also be an issue for large knotweed stands.

Cost of Suppression

Evaluation of the associated costs of control measures and the effectiveness associated with various techniques indicates that the most effective and cost-effective "primary" treatment measure would be to utilize the stem injection method. With a reported 95% reduction in stem count after one year this method and its delivery would likely produce the best results. A cost comparison of three different herbicide application techniques is shown in Table 2. These comparisons are based on an average of 47% efficacy between all techniques.

Estimated Cost for ***Foliar Application of Herbicide*** *of Japanese Knotweed*						
Site	**Sq. Ft.**	**Cost/Sq. Ft.**	**Total year 1**	**Total Year 2***	**Total Year 3***	**Grand***
Estuary	8,778.31	0.09	$790.05	$418.73	$221.92	$1,430.70
River (Upstream)	262,360.04	0.09	$23,612.40	$12,514.57	$6,632.72	$42,759.70
Incidentials 5%			$1,110.00	$1,110.00	$1,110.00	$3,330.00
Total	271,138.35		$25,512.45	$14,043.30	$7,964.65	**$47,520.40**
Estimated Cost for ***Stem Injection Treatment*** *of Japanese Knotweed*						
Site	**Sq. Ft.**	**Cost/Sq. Ft.****	**Total year 1**	**Total Year 2***	**Total Year 3***	**Grand***
Estuary	8,778.31	0.15	$1,316.75	$697.88	$369.87	$2,384.50
River (Upstream)	262,360.04	0.15	$39,354.01	$20,857.62	$11,054.54	$71,266.17
Incidentials 5%			$1,110.00	$1,110.00	$1,110.00	$3,330.00
Total	271,138.35		$41,780.75	$22,665.50	$12,534.41	**$76,980.67**
Estimated Cost for ***Cut Stump Treatment*** *of Japanese Knotweed*						
Site	**Sq. Ft.**	**Cost/Sq. Ft.****	**Total year 1**	**Total Year 2***	**Total Year 3***	**Grand***
Estuary	8,778.31	0.25	$2,194.58	$1,163.13	$616.46	$3,974.16
River (Upstream)	262,360.04	0.25	$65,590.01	$34,762.71	$18,424.23	$118,776.95
Incidentials 5%			$1,110.00	$1,110.00	$1,110.00	$3,330.00
Total	271,138.35		$68,894.59	$37,035.83	$20,150.69	**$126,081.11**

* Assumes an average 47% reduction in stems (efficacy) each year following treatment.
** Cost per sq ft based on an average stem density of 1 stem per square foot (1 sq.ft. = 1 stem)
Note: Assumes the use of Glyphosate- based herbicided for all treatment methods.

Cost "estimates" based on: One person (*licensed applicator*) plus indirect costs, travel time, cost of chemicals and reporting time. Also included are on-site prep time and application times. Does not include capitol costs for equipment. Calculated by R. Williams, 2012.

Table 2: Three-year cost estimate calculations for three management strategies for control of Japanese knotweed on the Salmon River.

Long-Term Monitoring

Long-term monitoring costs could be absorbed by utilizing SLELO-PRISM seasonal employees or in-kind contributions from partner organizations.

Reducing Costs

To increase the feasibility of knotweed suppression by stabilizing the costs, an alternate implementation strategy could be considered. This strategy would be based on the following:

- Divide the treatment areas into two separate zones and treat one zone with contracted services and the other using our seasonal employee whom is a pesticide applicator.
- Assume a 90% efficacy of post-treatment knotweed populations.
- Average the costs over the first three years recognizing that year two may have carryover from year one in initial treatments.

Dividing the treatment areas into two zones would be as follows: Zone one would be the estuary portion of the Salmon River. This area has been previously defined as the area within the influence of

Lake Ontario's water levels. Treatment in this area would be accomplished utilizing a SLELO seasonal employee whom is a licensed pesticide applicator. Given this individual's other work assignments, this area could feasibly be worked into his schedule. Zone two would consist of the upstream or main stem of the river. Due to the abundance of knotweed populations this area would likely benefit from a contracted licensed applicator.

The combination of work by a seasonal employee and contracted services should allow for a broader scope of suppression within the two whole systems. Working cooperatively to obtain landowner permission, conduct applications and to ensure follow-up would create a more complete approach to suppressing knotweed on this system.

If a 90% efficacy can be achieved with stem injection, then the costs would be reduced (Table 3). Dividing the treatment costs alone over a three year period bring the estimated annual cost to $15,048.18 for treatment only.

Three-Year Average for Total Stem Injection Treatment Costs - Assuming 90% Efficacy, No Incidentals						
Sq. Ft.	**Cost/Sq. Ft.**	**Total year 1**	**Total Year 2**	**Total Year 3**	**Grand Total**	**Average Cost Per Year**
271,138.35	0.15	$40,670.75	$4,067.08	$406.71	$45,144.54	**$15,048.18**

Table 3: Costs for stem-injection suppression treatment averaged over a three-year period, assuming 90% efficacy..

Evaluation

After careful evaluation of the contributors to this feasibility assessment, and based on the outcome of the Invasive Plant Management Decision Analyses Tool (IPMDAT)[2], it is felt that a comprehensive plan to address the threats to this resource is feasible. Suppression of knotweed populations may be considered as one component of a restoration effort complimented by native plant restoration in disturbed areas. This would promote native riparian plant growth, restore streamside habitat, stabilize the riverbanks and serve as a conservation element of the overall effort.

Objective No. 2 *– Restore treated areas by allowing for native regrowth and by intentionally planting native species of riparian plants.*

In addition to knotweed suppression and native plant restoration and educational component would be beneficial to the surrounding communities and angler user group. This component could take many forms and should provide for a more comprehensive conservation effort. Ideally a pre-implementation outreach effort should take place to educate the audience about the benefits of this conservation effort. Additionally, an educational component may serve to promote long-term stewardship of the Salmon River as a natural resource.

Objective No. 3 *– Implement an education & outreach effort to a targeted audience to garnish informed consent and to prevent future introductions of knotweed and other invasive species.*

The combination of all these components creates a more comprehensive approach to restoring the Salmon River Corridor and the Salmon River Estuary.

[2] A tool designed to promote critical thinking and due diligence to assist in the decision making process of invasive species treatment.

Recommendation

Implement a Salmon River Initiative

The Salmon River combines the cultural resources of a world-class fishery attracting thousands of anglers to the area on an annual basis which an estimated 20 million into the local economy, annually. The river (and estuary) provides important natural aquatic habitats that include wetland nesting areas and spawning areas for native species such as the Northern Pike, Black Tern and Least Bittern.

Based on the findings contained within this report, the feasibility of managing the river corridor and estuary towards a more divers and native landscape is possible. Additionally, it is generally felt that by combining multiple elements into an "initiative" would bring the best results. A Salmon River Initiative may include the following components;

- **Suppression of Riparian Japanese Knotweed populations: (cost $39,840.00)[3]**

As noted in this report, populations of knotweed can be separated into two distinct areas consisting of the estuary portion and the upstream portion. Assuming a 90% efficacy using a combination of stem injection and follow-up foliar application of systemic herbicides on all riparian population (sustained over three years) will likely have an observable reduction in knotweed populations. Private lands should be treated with landowner permission where allowed. In areas where access is "denied" a consistent effort should be made to educate and encourage landowners.

- **Native Plant Restoration: (cost $7,200.00)[4]**

Restore treated (upstream) sites by planting & promoting riparian native plants. This effort will help stimulate regrowth of native plants along the river corridor. Purchasing certified native plants and planting via citizen science/community volunteers, would provide not only for native plant restoration but also provide for community awareness and appreciation for this resource. To reduce costs within this component a donation from DEC Saratoga Nursery may be a possibility, cost would therefore be 0.00.

- **Education & Outreach: (Cost = $1,500)**

Placing value and appreciation for this resource while attempting to change behavior is an important component of this initiative. This component could be used as a match from SLELO funds. Educational components may include;

  - Small ground signs identifying conservation plantings and their importance (would educate and prevent trampling).

[3] Based on 90% efficacy using stem injection method.
[4] Based on average costs and "spot planting" - Could request a native plant donation from NYS DEC Saratoga Nursery.

- Salmon River Initiative “packets” that include all sorts of materials could be developed and disseminated.
- Perhaps bring back a “River Steward” to work on the river during peak season September – October.

Funding the Salmon River Initiative:

Scenario 1 – Begin the first year of the project using SLELO funds and apply for grant funds from the Great Lake Initiative (GLRI) to be used in 3 subsequent years. If funded this would allow for a total of four (4) years of treatment. Must be prepared to utilize at least three years of SLELO funds in the event that outside grants cannot be obtained.

Scenario 2 – Utilize three years of SLELO funding. This will allow partners to get started right away and sustain the effort for at least three years.

Scenario 3 – Hold the “Initiative” for a future grant proposal, perhaps to GLRI. This will allow partners to utilize grant funds for the project and save SLELO funds for other efforts. Risk is that the initiative does not get funded.

3-Year Budget (assumes averaging the costs over a minimum three year period and assumes a 90% efficacy using the stem injection method outlined in this report).

	Suppression	**Restoration**	**Education**	Total
Year 1	$20,000.00	$2,400.00	$500.00	$22,900.00
Year 2	$15,180.00	$2,400.00	$500.00	$18,080.00
Year 3	$ 4,660.00	$2,400.00	$500.00	$ 7,560.00
Totals	$39,840.00	$7,200.00	$1,500.00	**$48,540.00**

Notes:

The average price for established native riparian plants (1 to 2 ft in height/established roots) is $8.00. Using a general “spot planting” scenario 300 plants per year x three years = 900 plants ($7,200.00)

St. Lawrence Nurseries
325 St. Hwy. 345, Potsdam-Madrid Rd., Potsdam, NY 13676. Tel: 315/265-0778
E-mail: trees@sln.potsdam.ny.us Web: www.sln.potsdam.ny.us

Appendix I

Method for Estimating Total Japanese Knotweed Infested Area on the Salmon River

Greg Chapman, October 2012

For the purposes of determining the feasibility of Japanese knotweed suppression along the Salmon River, a rough estimate was needed of the total area covered by Japanese knotweed. At this time no complete survey for Japanese knotweed has yet been undertaken on the Salmon River, however the results of several incomplete surveys were available. These previous results were used to estimate the total extent of Japanese knotweed along portions of the river that had not been surveyed. Due to the amount of estimation involved in determining this total area, the result should only be considered a very rough approximation.

Existing survey data came from several sources:

1. A presence/absence survey for several riparian invasive species, including Japanese knotweed, was completed along a portion of the Salmon River in August of 2011. This survey was conducted by foot and covered a majority of the area from the upstream limit of the Douglaston Salmon Run (near the Pulaski Municipal Sewage Treatment facility) to a point upstream of the area known as the "Sportsman's Pool." No data relating to the area of Japanese knotweed patches observed during this survey was collected; only patch location data was recorded.

2. A Japanese knotweed assessment was completed within the Salmon River Freshwater Estuary in July of 2012. This survey was completed by canoe and included visual observation of all shoreline within the estuary as well as a portion of the river upstream from the estuary's upper limit. Area for each recorded patch of Japanese knotweed was visually estimated.

3. Two additional foot surveys were completed in October of 2012. The first revisited a heavily infested stretch of river in the Village of Pulaski that had been previously inventoried during the 2011 survey (above) in order to gather data related to Japanese knotweed patch size and total density within the area. A second survey partially inventoried Japanese knotweed occurrences near the Village of Altmar in the upper Salmon River main stem. Patch area was visually estimated for those occurrences of Japanese knotweed observed during these two surveys.

This data was used to estimate the area occupied by Japanese knotweed in portions of the river known to be infested, but not formally surveyed. Anecdotal infestation information was provided both by Fran Verdoliva (NYSDEC Coordinator for the Salmon River) and from my own personal observations while conducting work along the Salmon River during the past four years.

Japanese knotweed density varies greatly between different stretches of the Salmon River; this was observed and measured directly during the various surveys, and is reported to be the case in non-surveyed areas as well. As such, both surveyed and non-surveyed stretches of the river were divided into compartments; within each separate compartment, the observed or reported density and distribution of Japanese knotweed occurrences was noted to be generally internally consistent.

Total land areas for each compartment was estimated by utilizing GIS software to calculate the gross area (in acres) of river compartment polygons created through visual inspection of aerial photographs. Japanese knotweed density (in square feet per acre) was calculated for surveyed compartments by dividing the total area of observed knotweed by the compartment's area. Japanese knotweed area within non-surveyed compartments was estimated by multiplying the area of the non-surveyed compartment with the calculated Japanese knotweed density of an adjacent surveyed compartment reported have a similar distribution of knotweed. For those areas where occurrence data was limited to patch locations without area data, the number of observed patches was multiplied by the average patch size within an adjacent surveyed compartment.

The following list describes the various compartments and the methods used to estimate Japanese knotweed area within those compartments that lacked survey data; see also Figures 1 and 2.

1. **Salmon River Freshwater Estuary.** This compartment was completely surveyed in July of 2012.
2. **Port Ontario Braided Open River.** This compartment is upstream of the upper limit of the Salmon River Freshwater Estuary and downstream of the western property boundary of the Douglaston Salmon Run (DSR). It was completely surveyed in July of 2012.
3. **DSR Braided Open River.** This compartment covers the western extent of the portion of the Salmon River that passes through the DSR, a private stretch of river with restricted access. Aerial photographs were visually inspected to estimate that portion of the river that was most similar to the Port Ontario Braided Open River (where the river is heavily braided with many islands and channels, and lacking any dense forestation). The amount of Japanese knotweed within this compartment was calculated by multiplying the known knotweed density (square feet per acre) of the Port Ontario Braided Open River with the area of the DSR Braided Open River.
4. **DSR Linear River.** This compartment covers the eastern extent of the portion of the Salmon River that passes through the DSR. This portion of the river is more linear with few islands, and is more densely forested, and is generally similar in these respects to the Salmon River as it passes through the Village of Pulaski, just upstream of the eastern boundary of the DSR. The amount of Japanese knotweed within this compartment was calculated by multiplying the known knotweed density (square feet per acre) of the Pulaski Linear River (compartment 6 below) with the area of the DSR Linear River.
5. **Pulaski Non-Area Samples.** These areas of the river, which are both upstream and downstream of the Pulaski Linear River compartment (below), were surveyed in 2011. These surveys did not include area estimations, but do provide the number of patches found along these stretches of river (which includes a significant stretch of river where no Japanese knotweed was found). The area occupied by these known patches was estimated by multiplying the number of observed patches with the average size of patches within the Pulaski Linear River compartment.
6. **Pulaski Linear River.** This compartment includes a heavily infested stretch of the Salmon River as it passes through Pulaski. Although surveyed in 2011, it was again sampled for patch size data

in October 2012 to provide data used in the estimation of Japanese knotweed area in the DSR Linear River compartment and for the Pulaski Samples that lacked area data as described above.

7. **Trout Brook Outlet to Trestle Pool.** This compartment, which stretches from a point downstream of the Trout Brook outlet to a point downstream of Trestle Pool, has not been formally surveyed. However, no knotweed has been observed or is reported to grow on this stretch of river (similar to the long knotweed-free surveyed stretch just below this compartment).

8. **Altmar (Non-Surveyed).** This compartment, downstream of the Altmar Sampled Compartment, has not been surveyed. Knotweed is known to grow sporadically along river shorelines within this braided but forested stretch of river. The amount of Japanese knotweed within this compartment was calculated by multiplying the known knotweed density (square feet per acre) of the Altmar Surveyed Compartment (compartment 9 below) with the area of the Altmar Non-Surveyed Compartment.

9. **Altmar (Surveyed).** This stretch of river, downstream of the bridge in the Village of Altmar, was surveyed in October of 2012.

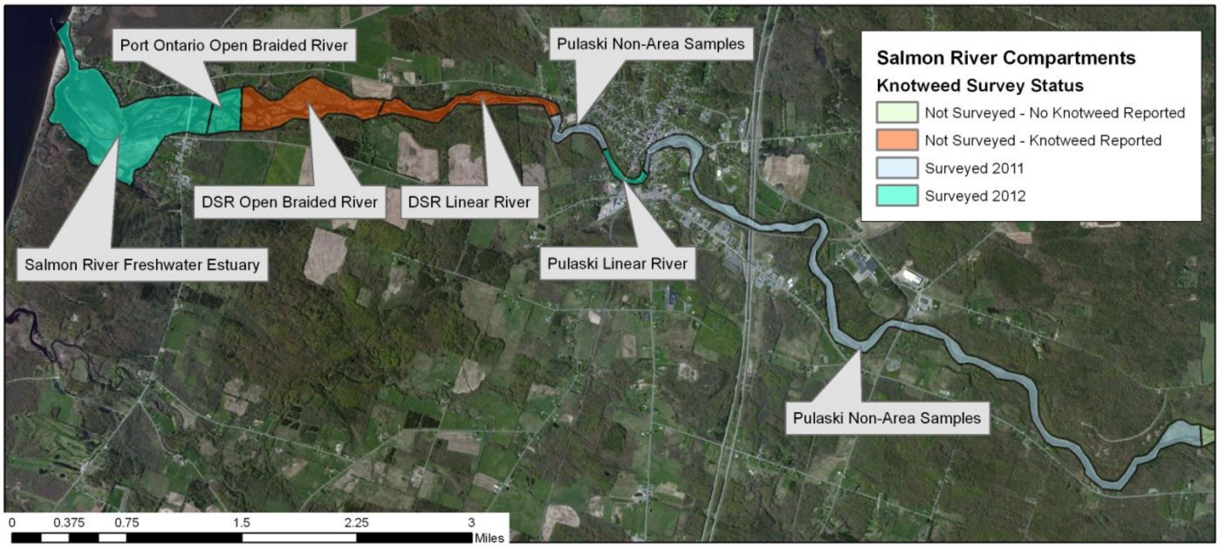
10. **Altmar to Lighthouse Hill Dam.** This compartment, which stretches from the bridge in the Village of Altmar upstream to the Lighthouse Hill Dam, has not been formally surveyed. However, no knotweed has been observed or is reported to grow on this stretch of river.

Calculations Table:

	Number Of Patches	Avg. Patch Size (sq ft)	JKW Total Area (sq ft)	Total Land Area (acres)	Density (sq ft/acre)	Calculated Total JKW (sq ft)
Salmon River Freshwater Estuary	8	1097.29	8778.31			8778.31
Port Ontario Open Braided River	17	2496.83	42446.04	35.05	1211.01	42446.04
DSR Open Braided River				115.97		140441.29
DSR Linear River				56.06		47360.87
Pulaski Linear River	22	448.91	9876.00	11.69	844.82	9876.00
Pulaski Non-Area Samples	21					9427.11
Altmar (Non-Surveyed)				59.46		12808.73
Altmar (Surveyed)	16	407.81	6525.00	30.29	215.42	6525.00
	Calculated values with red backgrounds indicate estimated areas				**Estimated Total JKW**	**271138.35**
						~6.37 Acres

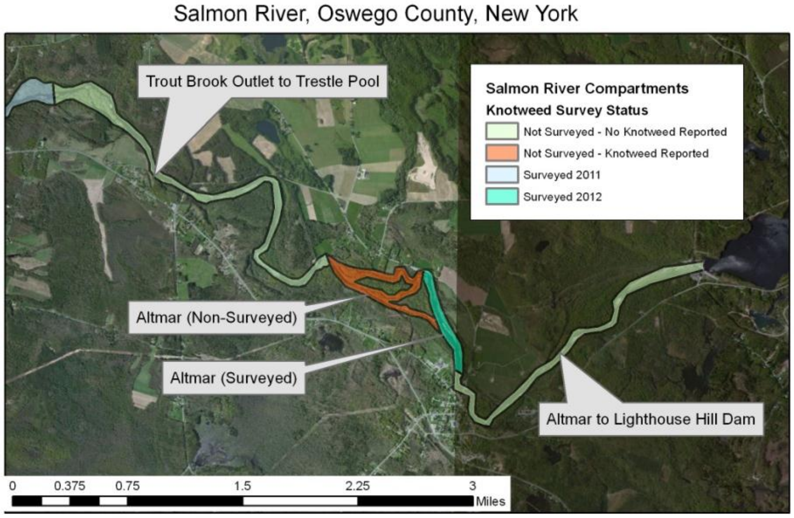
Compartments Used to Calculate Total Japanese Knotweed Area Estimate - Eastern River

Salmon River, Oswego County, New York



Compartments Used to Calculate Total
Japanese Knotweed Area Estimate - Western River

Salmon River, Oswego County, New York



Bibliography

Chapman, G. C. & McHale, M. T. (2012). Salmon River Estuary Japanese Knotweed Assessment. St. Lawrence - Eastern Lake Ontario Partnership for Regional Invasive Species Management, Pulaski, NY. Available at http://www.sleloinvasives.org/wp-content/uploads/2012/07/Salmon-River-Estuary-Knotweed-Assessment1.pdf [Retrieved November 5, 2012].

Connelly, N. A. & Brown, T. L. (2009). New York Statewide Angler Survey 2007, Report 1: Angler Effort and Expenditures. Bureau of Fisheries, New York State Department of Environmental Conservation, Albany, NY. Retrieved from http://www.dec.ny.gov/docs/fish_marine_pdf/nyswarpt1.pdf [November 8, 2012].

Focazio, P. C. (2006, Fall). Spotlight on the Salmon River. *Coastlines,* 35(3), 8-9. Retrieved from http://www.seagrant.sunysb.edu/Images/Uploads/PDFs/CL-Fall06.pdf [November 5, 2012].

Gleason, H. A., & Cronquist, A. (1995). *Manual of vascular plants of Northeastern United States and adjacent Canada*. Bronx, N.Y: The New York Botanical Garden.

Lowe S. J., Browne M. & Boudjelas S. (2000). 100 of the World's Worst Invasive Alien Species. IUCN/SSC Invasive Species Specialist Group (ISSG), Auckland, New Zealand. Retrieved from http://www.issg.org/pdf/publications/worst_100/english_100_worst.pdf [November 6, 2012].

McGee, G. G. (2008). Salmon River Watershed Natural Resources Assessment. Syracuse, NY: State University of New York College of Environmental Science and Forestry. Retrieved from http://www.dec.ny.gov/docs/regions_pdf/srwasa.pdf [November 5, 2012].

McHugh, J. M. (2006). A Review of Literature and Field Practices Focused on the Management and Control of Invasive Knotweed. The Nature Conservancy Southern Lake Champlain Valley Program, West Haven, VT. Retrieved from http://www.invasive.org/gist/moredocs/polspp02.pdf [November 6, 2012].

Prindle, S. E, & Bishop, D. L. (2011). Fall 2011 Lake Ontario Tributary Angler Survey. In NYS-DEC (Ed.), 2011 Annual Report, Bureau of Fisheries, Lake Ontario Unit and St. Lawrence River Unit to the Great Lakes Fishery Commission's Lake Ontario Committee. Retrieved from http://www.dec.ny.gov/docs/fish_marine_pdf/lorpt11.pdf [November 5, 2012].

Seiger, L. A. (1991). Element Stewardship Abstract for Polygonum cuspidatum. The Nature Conservancy, Arlington, VA. Retrieved from http://www.invasive.org/gist/ esadocs/documnts/polycus.pdf [November 5, 2012].

Shaw, R. H. & Seiger, L. A. (2002). Japanese knotweed. In: Van Driesche R. and others, technical coordinators. *Biological control of invasive plants in the eastern United States*. Amherst (MA): USDA Forest Service. Publication FHTET-2002-04. 413 p. Retrieved from http://wiki.bugwood.org/Archive:BCIPEUS/Fallopia_japonica_var._japonica [November 5, 2012].

Smith, C. L. (1985). *The Inland Fishes of New York State*. New York State Department of Environmental Conservation, Albany, NY.

Soll, J. (2004). Controlling Knotweed (Polygonum cuspidatum, P. sachalinense, P. polystachyum and hybrids) in the Pacific Northwest. The Nature Conservancy, Oregon Field Office. Retrieved from http://www.invasive.org/gist/moredocs/polspp01.pdf [November 6, 2012].

Soll, J., Kreuzer, D., Dumont, J., Matthews, I., & Hoeh, M. (2009). Sandy River Riparian Habitat Protection Project Report 2008. The Nature Conservancy, Oregon Field Office. Retrieved from http://www.invasive.org/gist/moredocs/polspp03.pdf [November 6, 2012].

Stuart, L. (2005, July 14). Knotweed overtaking UD habitat. *The River Reporter*, 31(28). Narrowsburg, NY. Retrieved from http://www.riverreporter.com/issues/05-07-14/feature.html [November 6, 2012].

Townsend, A. (1997). Japanese Knotweed: A Reputation Lost. *Arnoldia*, 57(3), 13-19. Retrieved from http://arnoldia.arboretum.harvard.edu/pdf/articles/471.pdf [November 6, 2012].

USFWS. (2001). Black Tern Habitat Model. United States Fish & Wildlife Service, Washington DC. Retrieved from http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/black_tern_model.htm [November 6, 2012].