

AN ABSTRACT OF THE CAPSTONE PROJECT OF

Timothy R. Kalke for the degree of Master of Natural Resources, presented July 16, 2015.

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Abstract

Increased energy costs have prompted the rural village of Galena, Alaska to explore viable alternatives for heat and power generation. Continued dependency on petroleum products will cause the community's economic driving force, the Galena Interior Learning Academy (GILA), to face uncertain operability. A wood-fired boiler is scheduled to be installed, replacing an antiquated diesel driven steam system. Collectively, several community entities have formed a non-profit organization, Sustainable Energy for Galena, Alaska, Inc. (SEGA), which has been tasked to provide the required biomass material. The purpose of this report is to describe the unique socio-ecological conditions within the Galena Working Circle (GWC) and to recommend management strategies that strive to balance a wide-range of local values. A properly implemented harvest management plan will place SEGA and the wood-fired utility in a position to help stabilize the community's economic foundation, promote valuable educational opportunities, sustainably utilize local fuel sources and introduce a new economic sector to the village. As the project matures from one phase to the next, a host of limitations (e.g., budget constraints, land access, weather conditions) and uncertainties (e.g., best handling and storage design, acceptable locations of harvest units) have and will continue to emerge. Fuel requirement calculations suggest 1800 gt of Balsam poplar at 40% MCwb will satisfy the annual heat load of 17.7×10^9 Btu. A well-organized fuel supply chain will need to incorporate in-field drying, cost effective transportation and a chip processing, storage and handling scenario appropriate for extreme weather conditions. Compared to the status quo, use of the wood-boiler system will provide a cost savings of nearly 50% for the end consumer. Public involvement in the decision-making process is key to utilizing a local renewable fuel source and developing a plan that allows efficient delivery without compromising the quality of life present within a unique rural lifestyle.

Sustainable Energy for Galena, Alaska: Timber Harvest Management Plan
by
Timothy R. Kalke

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I understand that my final report will become part of the permanent collection of the Oregon State University Master of Natural Resources Program. My signature below authorizes release of my final report to any reader upon request.



Timothy R. Kalke, Author

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I. General Project Site Information and Background

A. Introduction

The remote village of Galena, Alaska rests on the northern bank of the Yukon river, approximately 270 miles west of the nearest urban center, Fairbanks (Figure 1). Accessible via airplane or snow-machine in winter and water transport during warmer months, the community celebrates a unique blend of traditional Native Alaskan characteristics combined with attributes imported from an array of lifestyles and locations. Surrounded by an expansive swath of the northern boreal forest, community-members etch out a contemporary existence amid a rare set of dynamic environmental conditions.

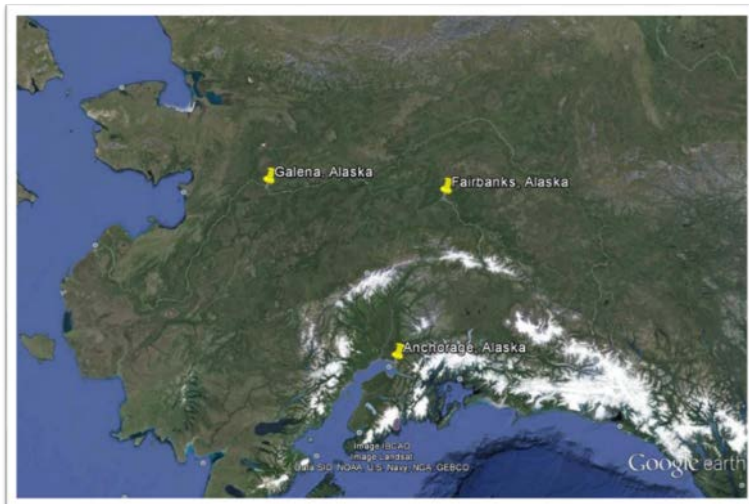


Figure 1 - Map of Alaska identifying location of Galena, in relation to urban centers of Anchorage and Fairbanks (Google Earth 2013).

Essential items

consistent with remote living (e.g., harvest of wild fish and game, home-gardening and procurement of fuel wood) can be derived from local supplies; however, a majority of goods

and services are imported via an expensive transportation

network. As cost of fossil fuel steadily increases and petroleum markets waver, many Galena institutions, community-members and other entities throughout rural Alaska have been prompted to explore alternatives for heat and power generation. Without a

feasible solution, the quality of life and standard of living found within these quiet villages face a host of uncertainties that threaten their sustainability.

A case in point is the operability of the Galena Interior Learning Academy (GILA), a premium regional boarding school embedded within the organizational framework of the Galena City School District (GCSD). GCSD stands as a local economic impetus and the community's largest employer, in no short order due to the large amount of students enrolled at GILA, respective to other rural Alaska communities. GILA is facilitated through the use of remnant infrastructure from the former Galena Air Base, now property of the City of Galena and leased by GCSD (State 2015).

A focal problem exists in finding a prudent solution for generating heat throughout the Air Base compound's numerous facilities (e.g., residential quarters, dining hall, gymnasium, composite building and various outlying support structures). Heat is currently produced with steam-boilers and distributed through an elaborate network of above and below ground utility pipes (i.e., district heat utilidor), constructed during the 1970's. The steam boilers are fueled by heavily subsidized diesel reserves (i.e., GCSD pays the equivalent of \$1.50 per gallon) purposefully allocated and stored by official agreement between City and Air Base personnel when ownership realigned. Based on average consumption, approximately 230,000 gallons per year, estimates indicate that reserves will become exhausted by 2017. If the current fossil-fuel system remains, GCSD might be confronted with a three-fold expense increase for heat (Dalson Energy 2013). This escalating allocation will significantly stress the quality and quantity of educational services offered, while unduly applying pressure to Galena's economic basis.

Use of alternative fuel sources for heat and power generation is not a new concept amongst residents of this remote region. Renewable and/or alternative energy projects have previously circulated the agendas of local entities without success. However, in recent years an initiative to install a wood-fired district heating system has taken root. When installed, the utility will complement upgrades to the current Air Base infrastructure and utilidor and potentially allow for future expansion. Conceptual designs are emerging from a contracted engineer firm (i.e., Dalson Energy) and will be constructed through grant funds (i.e., 3.4 million) awarded to the City by the Alaska Energy Authority (AEA), Renewable Energy Fund (Alaska Energy Authority 2014). The wood-fired system, owned and operated by the City, is scheduled to be active by October 2016 and will ease financial concerns, promote valuable educational opportunities, sustainably utilize local energy sources and introduce a new economic sector to the village (Dalson Energy 2014).

Prior to consideration for receiving awarded monies, many prerequisites were completed; including a construction feasibility study (Dalson Energy 2012) and forest inventory of lands within a ± 25 mile radius from the village center (i.e., the Galena

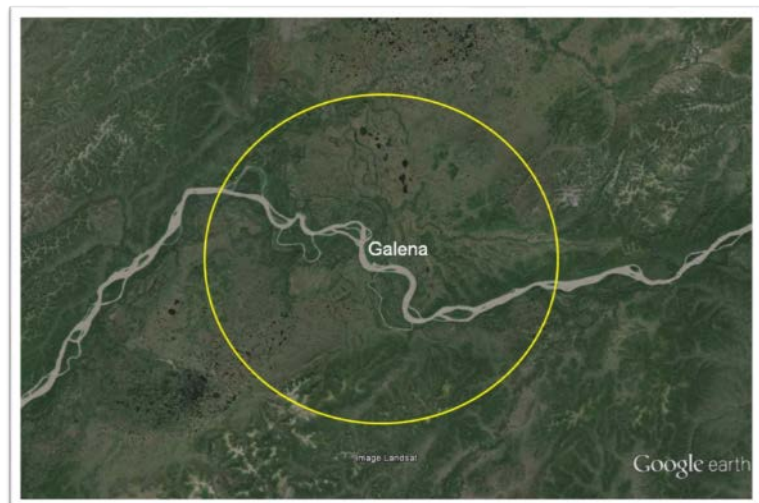


Figure 2 - Digital image of Galena's position along the Yukon River. Yellow circle represents the ± 25 mile radius of the Galena Working Circle (Google Earth 2013).

Working Circle (GWC)) (Figure 2; Stumpf 2013). Each element provided satisfactory

indications. Additionally, the primary landowner within close proximity to the village, Gana-A 'Yoo, Limited (GYL), the Native village corporation, has agreed to negotiate terms of a future Timber Sale contract.

Due to limited access, distance to sizeable markets, and low-market value of timber found, a commercially viable harvest entity has not previously existed (Wurst, Ott and Maisch 2006, 306). Regardless, the City of Galena, GCSD and Loudon Tribal Council (LTC), the local Indian tribal government, have become member entities of a non-profit organization, Sustainable Energy for Galena, Alaska Inc. (SEGA), whose primary purpose is to serve as a harvest entity and provide the City with a consistent supply of biomass fuel and, if available, additional products, which might include wholesale firewood and saw-logs for community members.

The purpose of this report is to describe the unique socio-ecological conditions within the Galena Working Circle and to recommend management strategies for SEGA's Timber Harvest Management Plan that address a wide-range of local values and considerations distinct to the regions remote environment. The content is a synthesis based on scientific literature, correspondence with industry professionals and field consultants, a collection of formal and informal discussions with local community members and preliminary estimates derived from an assortment of sources. Practices endorsed within are intended to contribute to project success, but are not to be interpreted as the only method available. Rather, plan aspects that require a specific application should be viewed as an opportunity for the reader to contemplate factors that lend toward achievement, while identifying potential design and operational pitfalls.

In order for this plan to have a sustainable contribution, strategies should to be refined with additional projections and ground-truth data and then selected with the integration of community perspective, support and involvement. This document is also intended to be used as a base from which a range of audiences (e.g., entity decision-makers, landowner shareholders) can contemplate interconnected pieces of the larger whole and lend insight toward specific details or broad themes during near and long-term planning sessions.

B. Historical Land and Resource Use

Koyukon-Athabascans (i.e., Tł' eeyagga Hut' aaninh) have had an established relationship with the land and its resources since time immemorial (Nelson 1983, 1). Occupying the Middle-Yukon and Koyukuk Valleys, the Koyukon depended upon abundant fish and game, as well as a plethora of other products that continue to be found within the Galena Working Circle. Semi-nomadic camps throughout the area were characterized by seasonal activities (e.g., fishing/hunting, berry-picking, winter activities). Harmonious relationships developed between social attributes and ecological functions, demonstrating appreciation and understanding of the human role within the larger ecosystem (Nelson 1983, 31).

For Koyukon inhabitants, the surrounding forest, consisting of a small variety of tree species, provided the essential ingredients for a warm place to call home and spiritual enlightenment. White spruce (*Picea glauca*) served as the primary source of heat and material for making “houses, boats, sleds, canoes, caches, tent frames, and countless other items” (Nelson 1983, 276). Black spruce (*Picea mariana*) was an acceptable alternative, for some purposes. Deciduous trees, such as paper birch

(*Betula neoalaskana*), balsam poplar (*Populus balsamifera*), thinleaf and green alder (*Alnus incana* and *Alnus viridis*), and a variety of willow species, fulfilled a host of special needs (e.g., bark baskets, lashings, smoking fish) (Chapin 2006, 82; Nelson 1983, 51).

Contact with outsiders was limited to other Alaskan Native groups (e.g., Inupiat, Yupik), until the late-1830's when a Russian trading post was established at the present site of Nulato (Wickersham 1938, 79). Early explorers affiliated with the Russian-America Company (RAC) used the Yukon River as a primary transportation route, due to its moderate flow and navigable distance. Later ventures targeted reaches near Nukluyet, present village of Tanana, in an attempt to expand available fur markets (Wickersham 1938, 80).

RAC transportation networks, accompanied by the Western Union Telegraph Company's attempt, from 1865-1867, to connect North America and Asia via cable line, resulted in limited timber extraction; however, shortly after the United States acquisition of the Alaskan Territory in 1867, the first steam-powered, stern-wheeled riverboat,



Figure 3 – “Wooding Up the S.S. Yukon below Circle City Alaska”
(Roessler 1997, 175)

Yukon, introduced the most significant era of logging throughout the rivers corridor (Wickersham 1938, 83-96). Harvest activity intensified on the Yukon through development of the Washington to Alaska Military Cable Telegraph System (WAMCATS), the 1886 discovery of gold on the 40-mile River and again in 1897 with the announcement of riches in the Klondike. Although the most significant mining activity was distant from the Galena Working Circle, the impacts of this historic event rippled far downstream.

The trading posts in Nulato, Koyukuk, and several other settlements provided steamers with cord-wood, some later became points of interest for other small-scale mining operations. The village of Ruby gained notoriety with the initial discovery of gold in 1907 (L' Ecuyer 1993, 1) and the village of Galena would find a spot on the map, serving as a supply depot and shipment location for lead ore, Galena, mined south of the Yukon (State 2015). *Nota' gheelet Denh* (i.e., *the place where the waters swirls around*) remains the present site of Galena.

While seasonal camps and associated activities continued to be important cultural attributes, by the late-1930's Ruby, Galena, Koyukuk, Kaltag and Nulato all had schools and residents began transforming toward more sedentary lifestyles. Galena became the regional hub, with the construction of a civilian airport in 1941 that later supported strategic military operations during World War II and again throughout Cold War tensions. Although an agreement was in place allowing joint-use between military and civilian aircraft, Alaska gained ownership of the airport after achieving Statehood in 1959. The official military presence ended in 1993 and ownership of remaining facilities and land was formally transitioned to local civilian entities by 2008 (State 2015).

Remnants of military activity are present throughout lands surrounding Galena (e.g., former landing-strips, training areas and shooting ranges). The majority of the impact falls within boundaries of State ownership; however, some activity did occur in areas that are now owned by GYL. GYL, the local Native village corporation, received ownership of approximately 430,000 acres, after four Alaska Native Claims Settlement Act (ANCSA) villages merged in 1978 (Gana-A 'Yoo Limited 1993, 9).

ANCSA created 13 regional and more than 200 village corporations, addressing some deeply-rooted indigenous land claim disputes. Additional legislation, the Alaska National Interest Lands Conservation Act (ANILCA) of 1980, extended boundaries of select federally protected lands by over 100 million acres. Within the GWC, evidence of ANCSA and ANILCA are prevalent with landownership designation distributed between Native corporations, Native allotments, Federal and State agencies and private entities.

C. Geographic Area, Biological and Ecological Drivers

Galena occupies a small segment of the much larger Yukon valley, approximately 50 miles east of where the Yukon and Koyukuk Rivers merge. To the north and northeast, the Koyukuk River makes a bend on its journey from the Brooks Range and the Gates of the Arctic. East of the village, the Kokrine Hills can easily be observed, bordering the Melozitna River to the north and welcoming the Nowitna Rivers confluence to the south. Passable in the winter, southern rolling hills and low-lands divide the Yukon and Kuskokwim Rivers. West is downstream, past the Unalakleet Mountains, the Bering Sea and on to the Pacific Ocean.

Landscape patterns vary from ponds and marshy wetlands, creeks, sloughs, oxbows, low-lying tussock fields, to minor ridgelines and wooded plateaus. Near the

outer perimeter of the GWC, lower elevations give way to more significant draws, valleys, spurs, rolling hills and mountain ranges. Terrain near the river's edge consists of eroded cut-banks with prominent cliffs in some locations and gentle rises in others.

Much of the GWC has been void of significant foreign disturbance, allowed to transition through the various stages of succession, while maintaining a healthy balance of ecological processes. Driven by natural disturbance regimes (e.g., fire, flood, herbivory), the typical pattern spans 200-250 years. Deciduous species (e.g., birch, poplar, alder, and willow) occupy early phases and transition to mature coniferous occupants (e.g., white and black spruce) in later stages (Chapin et al 2006, 100-120).

Diversity and abundance of wildlife in the boreal forest is heavily influenced by vegetative distribution and successional development (Figure 4). Many species are highly mobile and experience increased survivability, due to large swaths of suitable habitat. Conversely, some species lack the ability to safely transition between habitat locations and succumb to the ebb and flow of abundance and scarcity (Haggstrom and Kelleyhouse 1996, 59).

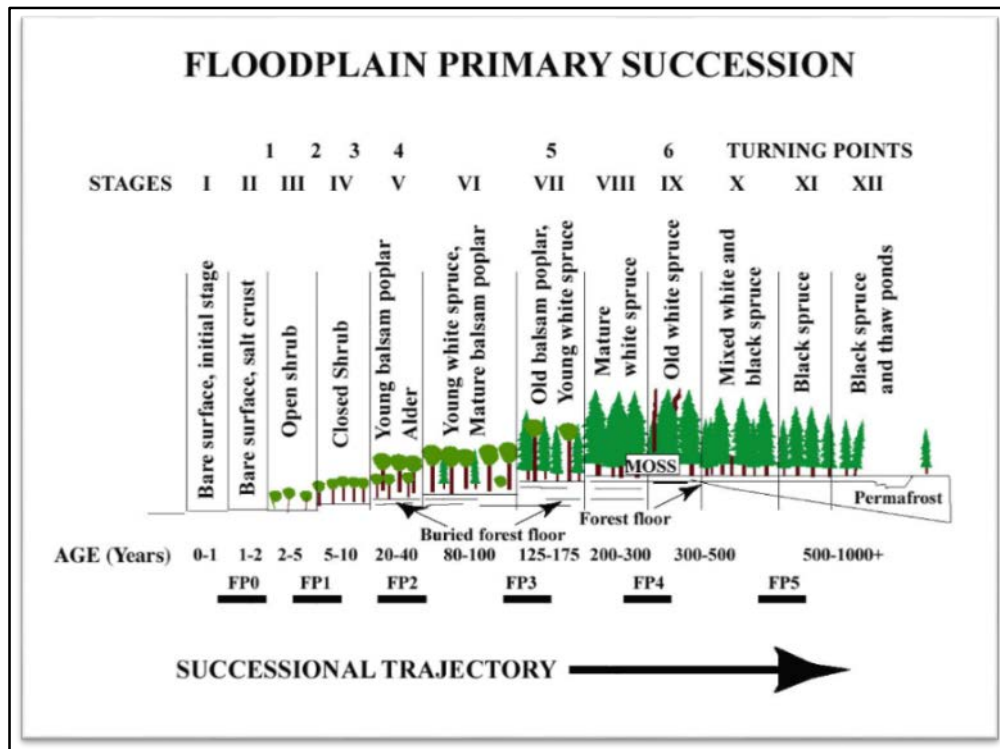


Figure 4 - The floodplain succession model presented provides a standard example of primary succession on surfaces that have not been previously vegetated.

Early successional species (e.g., willow, alder, and young poplar) satisfy dietary needs of several herbivorous inhabitants such as moose (*Alces alces*) and snowshoe hare (*Lepus americanus*), while mid-to-late stands serve as cover and protection. Intermixed throughout the canopy a host of cavity-nesting and insectivorous birds (e.g., woodpeckers, chickadees), raptors (e.g. bald eagle (*Haliaeetus leucocephalus*), Peregrine falcon (*Falco peregrinus*)) and spruce and roughed grouse (*Falcipennis canadensis* and *Bonasa umbellus*) thrive on available sustenance. Several forest species (e.g., marten (*Martes americana*), lynx (*Lynx canadensis*)) prey upon small mammals amongst large-woody debris found in late-successional stands, while other carnivorous species (wolverine (*Gulo gulo*), red fox (*Vulpes vulpes*) and wolves (*Canus Lupus*) capitalize on speed in open areas to track prey. Riparian areas function as migration corridors and provide critical habitat to beaver (*Castor canadensis*), river otter

(*Lutra canadensis*), grizzly (*Ursus arctos*) and black (*Ursus americanus*) bear (Haggstrom and Kelleyhouse 1996, 60-61).

It is understood that the biotic diversity of the boreal ecosystem is less complex than more temperate biomes; however, an intricate web of environmental factors compliment key ecological drivers to control forest structure and vegetation patterns. The GWC commonly experiences below freezing temperatures for eight months of the year with severe lows capable of reaching -50° F or colder. Despite a degree of snow cover throughout the winter, average accumulation rarely exceeds 24". Considered to be a relatively dry region, much of the precipitation comes during rainy months (e.g., July and August). While winter extremes dominate the landscape, the short summer growing season is punctuated with highs reaching $\pm 80^{\circ}$ F and sunshine for more than 22 hours per day. This unique blend of characteristics influences soil radiation, moisture and temperature. The region is part of the discontinuous permafrost zone, an identifiable attribute evident by the soils fluctuating ability to drain, causing reduced organic decomposition and restricted nutrient cycling. Furthermore, an assortment of mosses, lichens and other organic layers impact soil composition that lends control toward stand structure, function, productivity and dynamics (Bonan and Shugart 1989, 1-28).

II. Social, Cultural, Economic and Ethical Aspects

The Galena Biomass Project is dependent upon a host of variables and interactions (Figure 5) that influences its feasibility and potential to be a sustainable alternative for the community. An intricately interwoven component of this project is SEGAs Timber Harvest Management Plan. It is crucial that the plan for implementation capitalize on the wide range of benefits available (e.g., common values toward education and economic stability), as well as recognizing uncertainties that will require collaborative reconciliation (e.g., harvesting locations, impact on subsistence activities) and increase the likelihood of the development, in order to fully encompass any definition of sustainability.

Peak periods of military activity saw Galena's population soar to more than 1000.

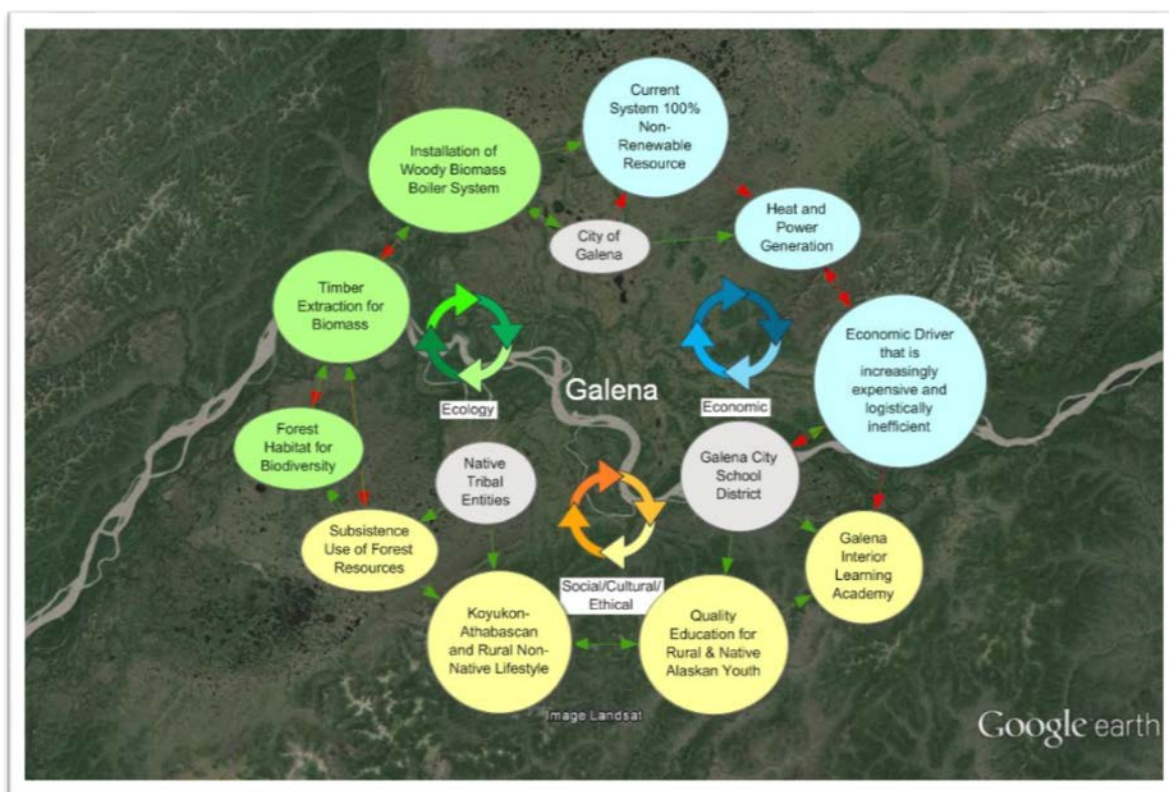


Figure 5 - Diagram of Interactions for the Galena Biomass Project (Google Earth 2013).

A 1981 state report predicted a future census over 2000 residents (Crook 1981, 170); however, 2010 statistics reveal that approximately 470 year-round residents lived within the survey boundaries, falling significantly short of previous estimates. Each winter, this figure increases with the arrival of > 200 regional boarding school students. Summer experiences another shift, when the GILA students depart and seasonal workers (e.g., BLM Wildland Fire Crews, construction labor) arrive to fulfill temporary positions. The majority of inhabitants are Alaskan Native, the remainder hail from across the globe (e.g., Western, European and Asian descent). (State of Alaska 2015).

For deeply-rooted families, and transplanted occupants, a vigorous forest ecosystem continues to be a crucial aspect of the village's social and cultural fabric. Procurement of primary necessities (e.g., fish, meat, fuelwood) through subsistence activities subsidizes the cost of living, and is dependent upon healthy forest functions (Kofinas et al 2010, 1348; Wolfe 2000, 1-4). A large variety of wildlife and an expansive panorama of wilderness provide ample opportunity for the most ardent recreational enthusiast. The wide ranging boreal landscape is prominent for a host of aesthetic, intrinsic and spiritual values, regardless of affiliation or denomination.

Indigenous subsistence activities have adapted, after having experienced an influx of market economy efficiencies (i.e., snow-machines, chainsaws and outboard motors replaced dog-teams, hand-held saws and skin or wooden boats) (Wilson 2014, 91). Despite the reduction of seasonal migration and rise of sedentary habits, a mixed-economy continues to play an important role and drive many aspects of the community. Ironically, contemporary elements that increased the standard of living now contribute to a struggling economic situation; a paradox that might negatively influence many social

aspects that are proportionally high in rural Alaska (e.g., teen drop-out rates, substance abuse, suicide rates) (Wexler et al 2014, 15).

Residential and commercial demands for fossil fuels (e.g., diesel, unleaded, propane) are burdened by extraordinarily high prices. A gallon of unleaded fuel, used for transportation, recently rose to \$8.00 at local pumps, diesel averages \$5.00 per gallon and a 100 pound canister of propane, commonly used for home appliances, nearly \$200. The cost of electricity is \$0.67 per Kwh and is partially subsidized (i.e., the first 500 Kwh used) by a State power-cost equalization program for residents. Domestic water delivered by City trucks costs \$.08 a gallon, \$.06 if retrieved independently. Furthermore, prices do not fluctuate with outside market adjustments; cost is based on price when supplier purchased and transported. Fuel is delivered via barge during the summer.

The Galena Biomass Project is positioned to introduce an economic sector that could further ease the strain of a struggling system and, at a minimum, stabilize the existing foundation (i.e., GCSD heat expenses), while additional measures are considered (e.g., energy-efficiency and weatherization projects, solar capability). Should the status quo remain, expenditures for fuel could rise by an estimated \$900k annually. Additionally, prescribed system improvements (e.g., distribution utilidor upgrades) will further improve efficiency, resulting in a decrease of fuel required (Dalson Energy 2014).

Local employment opportunities will add to the project value (e.g., management, harvest and chip processing operators, specialized mechanics). The product derived from this labor need not be limited to the biomass utility; harvest operations might also

be able to provide wholesale fuel-wood for residential use and/or saw-logs and house-logs available to private buyers. Future expansion of the utilities capabilities (e.g., Combined Heat and Power (CHP)) might present an opportunity for direct cost savings by private consumers.

An abundance of local benefits seem clear. The initiative could also serve as a model for other rural communities. However, several ethical aspects warrant attention. Even under the most stringent environmental consciousness, timber harvest will inflict an unnatural disturbance on the landscape; the activities will impact current biotic and abiotic processes. Access and conditions of areas that fulfill a variety of social uses will experience visible alterations. During an era of increased awareness and concern about global warming and climate change, carbon sequestration patterns will be periodically altered. Therefore, it is imperative that a robust planning process be used to implement activities and distribute risks and benefits in an acceptable manner to the community.

The matrix presented in Figure 6 is a starting point that might assist in identifying solutions for a variety of problems. The example below is derived from information gathered throughout the development of this report, but is limited to a single perspective and interpretation. While accurate to an extent, content needs to reflect the knowledge and opinion of a range of stakeholders, which could be constructed by future planning workgroups.

Problem(s)	Economic Factors	Social Factors	Ecological Factors	Suggested Management Strategies	Expected Outcomes
Rising costs of	\$0.67 Kwh cost	Increased cost of	GILA uses an	Weatherization &	~200k gallons of

fossil fuel based heat & power generation	for electricity	living	estimated 230k gallons diesel for heat	other efficiency upgrades	diesel fuel will be displaced and more affordable heat alternative available
	>\$5.00 p/gal cost for diesel	Increased stress on families	Non-renewable resource	Installation of wood biomass system	
	End of fuel subsidy created during Galena Air Base closure	Families moving to road system; areas with lower cost of living		Explore additional alternative sources of energy	
Sustainability of GILA infrastructure	Economic driver for community	GILA provides quality education for transient students, as well as unique opportunities for local youth	GILA has large carbon footprint, due to antiquated infrastructure and operational costs	Assessment & upgrades to infrastructure	High quality educational opportunities continue to develop for the state's 2 nd largest boarding school
				Implement energy saving strategies	
	Employs >100 residents			Consolidate high school operations to a single campus	Economic sustainability of GILA adds job security for a large number of residents, contributes to community resiliency, growth and quality of life
				Initiate regional resource programs (e.g., subsistence practices, Farm-to-Table programs)	
Maintaining Forest Health	Many products are used by local residents for personal, subsistence and/or commercial use	Subsistence activities depend on healthy forest functions	Co2 sequestration of interior boreal forest	Rotation harvest techniques include positive-impact strategies	Regional environment continues to support biotic and abiotic processes essential to overall ecosystem health
	Succession pattern supports use of woody biomass to displace >230k g/annually of diesel	Indigenous Cultural Traditions	Floodplain characteristics of Yukon River	Natural regeneration or reforestation programs (e.g., Agroforestry)	
		High value of aesthetically pleasing wilderness environment	Habitat for many species (e.g., Moose, Wolves, Beavers, Salmon)	Seasonality of harvest; on-site mitigation for insects/disease (e.g., bark beetle)	
Cultural & Subsistence Activities	Many families subsidize food & fuel expenditures with harvested forest products	Indigenous activities threatened by changing dependence on distant markets	Local & Traditional Ecological Knowledge (TEK) supports ethics & methods of sustainably utilizing forest resources	Incorporate TEK and patterns of subsistence activities into all phases of planning, operating and evaluating	Cultural & subsistence activities continue to provide integral components to rural lifestyle
		Established human use patterns in the area (e.g., trails, trap-lines, subsistence harvest, wood gathering)			Residents are contributing stakeholders in management decisions

Figure 6 – Matrix for the Galena Biomass Project

III. Organizational Management, Decision-Making & the Public

As the project matures from one phase to the next, a host of limitations (e.g., budget constraints, land access, weather conditions) and uncertainties (e.g., best handling and storage design, acceptable locations of harvest units) have and will continue to emerge. Leaders at all levels must continue to follow a process that facilitates inclusion of public perspective and an adaptive approach to finding accepted solutions.

There have been several community gatherings leading up to the creation of SEGA and the planned utility installation (e.g., acquiring grant funds, designing the utility and distribution system and components of future harvest scenarios). Engineers have presented technical information on specific items, such as various measures to improve heat efficiency (e.g., repair damaged or inoperable segments, switch from steam to hot-water distribution, install independent boilers in each building) and have gained invaluable insight from locals and employees with experience maintaining the current system.

Forestry professionals have performed inventories and feasibility assessments, utilizing local employees for timber cruises. Other forestry consultants have proven instrumental for acquiring a sales agreement and researching appropriate harvest equipment. As a result of these steps, decision-makers from three of the community's main entities (i.e., City Manager, GCSD Superintendent and LTC Administrator) have formally agreed to commit funds, time and effort toward the collaborative development of the project at-large and collectively organized a local timber harvest entity (i.e., SEGA). Throughout all of these events, GYL shareholders, community members and

entity representatives have had the opportunity to listen and provide feedback that has assisted in project development.

SEGA is organized with a board of directors, general manager and employees. There are a total of seven directors, four of whom fulfill official roles of SEGA (e.g., president, vice-president, treasurer, and secretary). Each director is appointed to the SEGA board by the respective member entity, two per. The seventh member is selected by the SEGA board to represent the community at-large. Throughout this report, reference to actions performed by SEGA implies that activities will be carried out by one or more associated individuals.

Since being organized, SEGA has used several occasions to share and gather information with audiences at regular, annual and special meetings. Quarterly distributed newsletters and media interviews (e.g., radio, television) have further increased public awareness. Formal and informal face-to-face discussions with a range of individuals (e.g., elders, entity leaders, GYL shareholders and other community members) have provided SEGA vital perspective on a range of topics and concerns (e.g., drying procedures, harvest locations, impact on residential wood-gathering, material storage & handling design).

While a formal survey of public opinion has not been conducted, the general impression gleaned from interactions is one of acceptance of the larger-project. This is not to suggest that dissenting opinions do not exist. An assortment of differing sentiments are likely present throughout the community. At this junction, large opposition has not surfaced, which might indicate that the economic stability brought by GILA is valued by the majority and therefore consent to the purpose of the harvest

activity in the early stages given. While there currently is no quantitative data available, initial qualitative research (i.e., personal interactions, interviews, observations) suggest substantial agreement with the above mentioned example.

A research supported response to this question is currently beyond the capacity of this report, but the notion does bring forth the recommendation that SEGA implement a transparent process for planning harvest activities and system for navigating future barriers and restraints. These capabilities might provide SEGA the opportunity to distribute risk and communal benefit between stakeholders and entities, while fulfilling the primary purpose of providing a reliable fuel supply. This concept is crucial; It is recommended that the fuel supply chain not be viewed as a linear progression from start to finish, but rather a cyclical flow geared toward sharing liability, communal benefits and individual advantages that serve multiple purposes.

In order to compliment the positive engagement strategies that have preceded SEGA and this report, it is recommended that an organized outreach program be employed that focuses on increasing public awareness, comment opportunities, and involvement in strategic (i.e., 10-100 years), tactical (i.e., 2-10 years) and operational (i.e., 1-2 years) planning efforts. It is understood that forest management decision-making is retained by the respective landowner (e.g., GYL); however, through a variety of activities, SEGA can position itself to gather local and traditional ecological knowledge (TEK) and incorporate these perspectives into annual operations that support long-term goals and objectives of the property owner.

Monthly and annual board meetings provide immediate forums for the public to provide comments and where official decisions can be shared; however, these

procedural gatherings often lack the atmosphere or conditions that allow comfortable exchanges for all. The following list is a set of suggested methods that could be used to increase public awareness and provide comment opportunities, regarding harvest activities.

- Newsletters posted on community bulletin boards (e.g., post office, grocery store, tribal council, airport, elementary and high school) and distributed via mail and/or e-mail with contact information. Postings could be accompanied by anonymous drop-boxes positioned with comment slips.
- Radio interviews for local news broadcast and advertisements during daily announcements.
- Encourage visitation to office at scheduled intervals (e.g., Monday morning coffee and cinnamon rolls).
- Share and maintain up-to-date information on website and other social media forums.
- Interactive and informational booths at community events (e.g., Agricultural Fair, Spring Carnival, Christmas Bizarre).
- Host well-advertised field-trips to past, present and future harvest locations. While exercising stringent safety protocols, these site visits could provide locals the opportunity to observe harvest activity (e.g., the dangle head processor in-action) and results of positive harvesting strategies (e.g., avoidance of soil compaction that promotes natural regeneration).

Within the agenda of each of these strategies, an open, caring and respectful setting should highlight the atmosphere. This might be achieved through practice of active-listening (e.g., avoid interjecting, culturally sensitive verbal and non-verbal cues used appropriately (e.g., pause-patterns, raising or furrowing the brow)), speaking when asked), communicating in a manner that is easily understood and maintaining a visibly positive presence. Maps, posters, decision and option matrixes and other visual

products should consolidate essential information and avoid overwhelming content arrangements (e.g., lots of small photographs and text).

With permission of participant, an observable method of collecting information should be used to demonstrate importance and to ensure accuracy. Follow-up inquiries via phone, e-mail, and postage mail or face-to-face should be prompt and sincere. It is imperative that outreach initiatives clearly emphasize the value of mutual learning; meaning that events are not intended to be a one-way, top-down distribution of education; rather, we can all learn from each other, as long as we are willing to communicate and listen with respect to individual and group comfort levels.

The items presented thus far have been centered on informal or coincidental participation that should be complimented by an organized interactive planning framework. In support of this notion, it is recommended that SEGA strives to facilitate a harvest management plan working group that functions with the purpose of providing opportunity to learn about harvest strategies and assist SEGA in making better decisions.

Prior to execution, SEGA personnel would need to formulate a thorough plan founded upon clear and realistic goals and objectives (e.g., explain how production and regeneration objectives will align with GYL requirements, identify ways the working group will help accomplish these items, create a system that helps manage future timber sale areas) (Shindler and Gordon 2005, 1-2). Having well-defined participant roles is critical. These might include;

- Present a wide-range of community values.
- Determine socially desirable management directions.

- Convey local knowledge into decision making.
- Allow experimentation of new approaches and strategies.
- Build trust and foster relationships amongst participants.
- Give the process acceptability

Contributions would be used to help resolve conflicts, negotiate problems and attempt to develop consensus about management strategies (Chambers and Beckley 2003, 115).

Additional upfront planning requires identification of necessary resources and appropriate individuals that are ready, willing and able. It is recommended that solicitation of motivated leaders begin with the GYL Natural Resources committee and Loudon Tribal Council (i.e., LTC). Consideration should also be given to how the effort will be perceived. What existing expectations do community members have about management groups in the area (Shindler and Gordon 2005, 1-2)? By having strong local leaders involved, the hope would be that others would realize that their voice can be heard and influence the decisions of SEGA.

Open to all, the working group should consist of GYL shareholders, LTC members and other community members. Involvement of representatives, in an official capacity, from neighboring landowners (e.g., State, BLM, and USFWS) is encouraged and at times critical. Formal group size will likely be determined by the local leaders involved. While maximum participation is encouraged, certain components might serve best with smaller numbers. This too would be a point to navigate amongst those concerned.

Sessions could occur on a bi-monthly or quarterly schedule with principle procedures established (e.g., group decision-making process, expectations for communicating and listening) and reiterated at the beginning. There are a slew of important ideas and concepts that could be the focus. Impacts on wildlife habitat (e.g., moose browse), strategic route access, and implications for residential firewood harvesting are examples that might align with other topics (e.g., regeneration features of harvested species, fragmentation, fuels reduction strategies). Correlating and incrementally presenting information regarding SEGA's fuel requirements and supply strategy might assist participants in piecing together the many interconnected components of harvest operations and their impacts toward the fundamentals of sustainability (i.e., social, cultural, economic, ecological and ethical aspects).

It is recommended that SEGA implement and adapt a set of positive-impact harvest strategies for a range of ecological considerations. While the purposes of these strategies (e.g., maintain wildlife habitat) often overlap with social concerns, it is recommended that the working group aid SEGA in developing a set of applications for promoting direct positive measures for other public issues. For example, predetermined buffer strips might be appropriate for maintaining or creating trap-lines. Retaining a percentage of specific stand types might create access to and support local firewood gathering.

Group participants could also serve well as a resource for collecting and analyzing data from measurable indicators (e.g., area of willow and alder regrowth) related to specific issues (e.g., improved moose habitat). This could provide interesting perspective between local and technical interpretations of results and generate

discussion and recommendations that guide future management strategies. This would aid in an adaptive management process that incorporates local knowledge and a cycle of implementation, monitoring, evaluation and adjustment (Rempel, Andison and Hannon 2004, 83-84).

The current timber sale area is expected to provide suitable volume for 20 harvest seasons and encompasses more than 4000 acres. While initial harvesting is restricted to the existing boundary, it is recommended that the working group also focus on long-term strategic planning for this area with outcomes that connect to lands beyond. Strategic goals and objectives that then drive tactical planning and annual operations. While plans center on obtaining the required fuel, support of other important aspects is crucial. It is recommended that the group begin with a thorough review and understanding of the values, goals and objectives of each entity involved (e.g., City of Galena, GCSD, and LTC). Consultation with the appropriate professionals may be advised (e.g., forest engineers). Regular discussion and collaboration with GYL and other landowners is imperative.

Interactions and learning opportunities that extend beyond harvest planning, should be offered and implemented over time. SEGA is a non-profit organization, currently pursuing Federal tax exemption status for educational purposes. Each harvest season could provide grounds for local educational offerings and research that supports higher academia. GCSD has recently launched a Natural Resources Management program, which initially will consist of two introductory courses aligned with University of Alaska-Fairbanks (UAF) to provide college-credit for eligible students (i.e., students who fulfill the requirements). It is recommended that SEGA promote this program and work

to expand available summer courses that align with resource management, sustainable energy and use of wood products. Examples include;

- Fire Science / Wildland Fire Fighter Training for Red Card
- Sustainable Agriculture & Green House Management
- Wilderness Leadership Education
- Forestry Technician
- Log Construction
- Heavy Equipment Operator
- Power Generation
- Rural Development

As SEGA fulfills the City's goal of having a consistent supply of biomass fuel, revenue generated from sales could support GCSD's program and/or fund summer courses, technical training and youth employment opportunities that align with GCSD and LTC strategic plans. For example, it is common that some students, who have flourished in the safe and positive setting of GILA, express severe trepidation about returning to unhealthy circumstances at the end of the school year. Their departure risks unraveling past achievements. Successes that could be further realized, if an opportunity to continue was made available. This type of residual benefit exemplifies the cyclical nature of the project, by providing the entity at the bottom of the fuel supply chain (i.e., GCSD).

These programs could further be improved with acquisition of outside funding sources (e.g., UAF, other grant awarding institutions). With agreement from GYL, students could inventory and monitor forest resources or write individual management

plans, both are objectives within the GYL Forest Stewardship plan. The above example is one thread that demonstrates the capability of fulfilling multiple entity goals through harvest activities and distributes the balance beyond the economic bottom-line. As a local elder once told this author, SEGA's final product is not a chip set to a certain specification; rather, it is a student walking across the stage with diploma in hand.

IV. Fuel Requirements

A. Heat Load

Events leading to the installation of the wood-fired boiler will promote significant moments of transition for all entities involved. Planning calculations for the initial season must then begin with baseline assumptions that are refined through execution of well-developed data collection protocols (Table 1). The results of these activities will shed valuable insight to compliment a steep increase of experience and learning.

Table 1 – Baseline assumptions for calculating volume.

Baseline assumptions	
Cost of Diesel	\$5
Total Heat Input	19.6 x10 ⁹ Btu
Total Heat Input (Wood)	17.7 x10 ⁹ Btu
Total Heat Output	14.7 x10 ⁹ Btu
HHV (Balsam Poplar)	8100 Btu
MC _{wb}	40%
SG green volume	.31
Den _{db}	19.3 lb/cf
Volume/acre	4100 cf/acre

Within the central steam plant (CSP), three Cleaver-Brooks steam-boilers, capable of more than 13 MMBtu/h output each, currently heat 14 of 22 buildings (i.e., 204,653 sf). Unfortunately, actual total and building input load is not available from CSP records. Future load requirements have been predicted during an utilidor study performed by a contracted assessor who collected data from a field

survey, previous third-party audits, and oil consumption data (Koontz 2013, 7). For the current system, projected total annual steam output is 14.6 million pounds of steam with a peak for building loads equaling 5368 lb/h (Koontz 2013, 8). Furthermore, an estimated 44% of boiler output is lost to utilidor, condensate and other system inefficiencies (Dalson Energy 2014, 1). This means that only half of the energy output of the boilers is actually available for building heat.

While the installation of a wood-fired boiler is imminent, the supporting distribution system and other efficiency upgrades continue to be investigated. It is most likely that the final conceptual design will include a newly placed district hot-water system primarily heated by a wood-boiler (i.e., KOB Pryotec capable of 4.3 mBtu/h). Two of the existing diesel steam-boilers will be converted for hot-water and will supplement during peak cold periods (i.e., approximately 10% of total input) (Table 2). With the new lines in-place, estimated total gross heat input required from both wood and oil reaches 19.6×10^9 Btu. Wood is estimated to contribute 17.7×10^9 Btu (i.e., 90% of the load) and oil will subsidize the remainder. When 75% efficiency is applied the total heat output generated is approximately 14.7×10^9 Btu.

Table 2 – Predicted load profiles, current steam (lb/h) and recommended hot-water wood and oil system (kBtu/h). Total equals building load plus losses (Koontz 2013, 8).

Outside Air Temperature (OAT)	Total Load (lb/h)	Total Load (kBtu/h)
75	1479	412
65	1524	451
55	1967	850
45	2458	1289
35	2953	1732
25	3446	2175
15	3917	2617
5	4373	3059
(5)	4828	3485
(15)	5281	3901
(25)	5733	4317
(35)	6184	4733
(45)	6634	5148
(55)	7083	5564

B. Material

1. High-Heat Value

Several suitable species of trees (e.g., white spruce, Alaskan birch, balsam poplar, willow) are found within the GWC that could provide satisfactory heat values, given certain circumstances. Of these options, balsam poplar, locally known as Cottonwood and from here referred to as poplar, has been targeted as the primary source of fuel for the initial heating seasons. Large volumes of poplar are prevalent within close proximity to the village making it an attractive candidate for early-project harvesting, while minimizing cost of production. Natural regeneration characteristics (i.e., stump and root sprouting) and rapid early successional growth patterns support resilient qualities in the face of disturbance. Poplar is rarely desired for residential heating purposes and ranks low in cultural significance when compared to other species. In order to accurately forecast the volume of poplar required to generate 17.7

$\times 10^9$ Btu, several variables must be considered including; high heat value (HHV), moisture content wet basis (MC_{wb}), and density (den).

Tree species and their components (i.e., bark, lower-stem, upper-stem, branches and foliage) consist of varying percentages of cellulose, hemicellulose, lignin and small amounts of other extractives. The quantity of each can be measured through the use of a bomb calorimeter. Results are calculated to identify the materials calorific value (i.e., high-heating value (HHV)). Calorific values of various hardwood and softwood species range significantly; 6700 Btu/lb to 10,200 Btu/lb for hardwoods and 8000 Btu/lb to 12,200 Btu/lb for softwoods (Singh and KostECKY 1986, 1378).

The literature is rich on studies quantifying the calorific value of a variety of biomass materials. Several sources suggest that poplar has a mean calorific value between 8090 Btu/lb to 8500 Btu/lb (Singh and KostECKY 1986, 1378; Strong 1980, 2). Older poplar (i.e., equal to or > 7 years old) are reported to have a lower HHV (e.g., 8060 Btu/lb) than younger regrowth < 7 years (e.g., 8500 Btu/lb) (Byrd 2013, 31). This is consistent with other studies that provided data pertaining to other *populus* species (8100 Btu/lb) and hardwood averages (8170 Btu/lb) (Demirbas 1997, 432; Telmo and Lousada 2011, 1665). Based on these findings, it is recommended that SEGA utilize the HHV of 8100 Btu/lb for extracted poplar.

2. Moisture Content

Balsam poplar has a proportionately high MC_{wb} , when compared to other boreal species. Therefore, it is critical that a keen awareness of MC_{wb} be present in all calculations.

$$MC_{wb} = \text{Water (WT)} / \text{Total (WT)}$$

Previous testing of samples in Ft. Yukon, AK, with the same species and under similar environmental conditions, has provided a glimpse toward what drying might be expected. In November 2013, poplar samples were harvested and decked in whole-tree form. After eight-months, a sample of these logs was chipped into a five-foot high pile and left uncovered. After one complete drying season, an oven-dry method was used to test two samples from the center of the pile in January 2015 with results averaging 39.5% MC_{wb} . This is drier than was to be expected.

Weight loss rate per week for a similar tree species (i.e., aspen) has been reported to be 0.7 percent (Droessler 1986, 3). This value applied in a model suggests that 51% MC_{wb} will be the result after 20 weeks (Table 3). This simple prediction method is helpful, but should be armed with the caveat that hot and dry periods will experience more moisture loss, while rainy humid periods less (Droessler 1986, 3).

Table 3 – Predicted % MC_{wb} based on a weekly weight loss rate of 0.7 (Droessler 1986). Model was received from Peter Crimp of Dalson Energy, through personal correspondence.

Week	Projected	Weight Wood	Weight Water	Projected
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	Weight Total			MC _{wb}
	2000	852	1148	57%
2	1972	852	1134	57%
4	1945	852	1093	56%
6	1917	852	1065	56%
8	1891	852	1039	55%
10	1864	852	1012	54%
12	1838	852	986	54%
14	1813	852	961	53%
16	1787	852	935	52%
18	1762	852	910	52%
20	1738	852	886	51%

Procedures of an initial analysis in Galena are on-going; however, MC_{wb} results for four local poplar samples, harvested in November 2014, averaged 57% using an oven-dry method. When hand-held meters were used, for the same samples in Galena, they measured 40% MC_{wb}. Similar results (i.e., 40% MC_{wb}), using a hand-held monitor, were reported from logs in Ft. Yukon, after they had been decked for six-months (i.e., throughout the winter), which indicates that little drying had occurred up to that time. While the inaccuracy of hand meters is understood and a host of variables impact drying rates (e.g., outside air temperature, precipitation), the comparison suggests that initial levels were similar and that Galena might anticipate comparable moisture loss readings, as those experienced in Ft. Yukon, after one-drying season (i.e., ~40% MC_{wb}).

It is recommended that planning efforts consider a series of MC_{wb} ratings (e.g., 30%, 40% and 57%), which result in decreased heat value respectively. For the initial year of operation, SEGA will only be able to provide material that has been exposed to one-drying season. Therefore, it is reasonable to coordinate efforts based on higher MC_{wb} values (i.e., 40%, 50%) and corresponding heat values rounded to two significant figures (i.e., 4900 Btu/lb, 4000 Btu/lb) (Table 4).

Table 4 – Effect of Moisture Content on the Heat Value of Balsam Poplar

Moisture Content (MC _{wb}) %								
	0	10	20	30	40	50	57	60
HHV (Btu/lb)	8100	7300	6500	5700	4900	4000	3500	3200

While loss of moisture is likely, it is important to recognize that change in MC_{wb} is dependent upon location of material in relation to surroundings (e.g., vegetation, slope, aspect and ground conditions) and environmental factors (e.g., precipitation, wind, humidity and maximum and minimum temperatures) (Raitila, Heiskanen, Routa, Kolstrom and Sikanen 2015, 1). Field drying is not guaranteed; under adverse conditions the potential exists that decked material could result in segments with an increased MC_{wb} (Droessler et al. 1986, 1). Several models exist for predicting moisture loss. It is recommended that a protocol be defined for predicting and monitoring drying for wood harvested in Galena. Results of these efforts can further refine the quantity of fuel need to satisfy necessary heat loads. The following volume estimates for this report will assume wood with 40% MC_{wb}. Further issues with seasoning poplar and recommended drying procedures will be discussed in Section V.

3. Weight and Density

Calculation of the green density, in lb/cf, of wood is a function of its specific gravity and MC_{wb}. Specific gravity (SG) can be computed using various methods; however, for wood, the standard is to use oven-dry mass and green volume approach (Ray 2015). It is recommended that 0.31 be used as a SG for poplar, which is

consistent with other sources (Miles and Smith 2009, 11; Peterson and Peterson 1992, 170; Ray 2015). This can be converted to dry-basis density (Den_{db}), in pounds of dry wood per cubic foot of green volume, by multiplying SG by the standard density of water, 62.4 lb/cf.

$$Den_{db} = SG \times 62.4 \text{ lb/cf} = 19.3 \text{ pounds of dry wood per cubic foot of green log.}$$

The dry-basis density can then be converted to wet basis to calculate green density at any MC_{wb} by the formula;

$$Den_{wb} = Den_{db} / 1 - (\%MC_{wb}/100)$$

The following example is shown for 40% MC_{wb} .

$$Den_{wb} = 19.3 \text{ lb/cf} / .6 = 32.2 \text{ lb/cf}$$

Further results of this method are reported in Table 5.

Table 5 – Estimated Green Density of Balsam Poplar (SG 0.31)

	Moisture Content (MC_{wb}) %							
	0	10	20	30	40	50	57	60
Den_{wb} (lb/cf)	19.3	21.4	24.1	27.6	32.2	38.6	44.9	48.2

4. Volume & Acreage

The baseline assumptions derived from the previous formulas allow for a more accurate calculation of volume needed to satisfy the estimated total annual input requirement of 17.7×10^9 Btu. The below equation can provide an estimated heat value per cubic foot,

$$Btu/cf = Btu/lb \times lb/cf$$

The values, 4900 Btu/lb (heat value at $40\%MC_{wb}$) $\times 32.2 \text{ lb/cf}$ (density at $40\% MC_{wb}$) equate to an estimated heat value of 158,000 Btu/cf of logs at $40\% MC_{wb}$. Based on these numbers, it is recommended that SEGA provide a minimum of 112,000 cf of poplar with a MC_{wb} of 40% or less. The total weight of this volume is equal to 1800 green tons (gt) or 1100 bone-dry tons (bd).

The acreage needed to extract the required volume is dependent upon vegetative distribution within harvest unit(s) and individual stand characteristics. Limited ground-truth inventory data are available for lands within the GWC. Data collected for a forest inventory, performed in 2012, comprised of samples from 63 field sites throughout the GWC (Stumpf 2012, 4). Conclusions from this report were beneficial in terms of promoting the larger project feasibility, but lacks detail for operational timber harvest planning. Regardless, the baseline assumption gleaned from this report, 1700 cf/acre for pure poplar stands, provides a starting point from which further planning can proceed (Stumpf 2012, 27).

Two preliminary timber cruises have performed randomly located sample plots (e.g., one fixed and one variable-radius plot) within patches of medium to old growth poplar that are targeted for harvest. Tree height was measured from 1' base to an

estimated 4" diameter top, using a hand-held laser-range finder. Plot sizes were 1/5th acre and 1/10th acre, respectively. Volume in cubic feet was calculated for all trees > 4" DBH within the plot radius using the formula,

$$V1 = -3.2187 + 0.8281D - 0.05908D^2 - 0.01985H + 0.00199D^2H$$

D being the diameter at breast height and *H* the height measured from 1' from base to an estimated 4" top (Gregory and Haack 1964, 19). This is not common practice, but considering the suggested equation was derived from down logs to 4" top, height was estimated to a 4" top to avoid overestimating tree volume. Results for the two plots averaged 4100 cf/acre (i.e., 3396.92 and 4764.31 cf/acre). SEGA is fortunate to have numerous patches of similar composition distributed throughout the southwestern portion of the timber sale area, which contributes validity to the limited samples performed thus far. However, it is clear that additional inventory data is critical, in order to capture a reliable baseline assumption for future planning. The low-end overall average value (i.e., 1700 cf/acre) provides perspective for future harvest rotations that could exceed 65 acres annually.

It must be noted that these initial plots were located in the center of high-quality stands and therefore can be used as a top-tier estimate for planning, rather than the expected norm. Additionally, the results include outside bark measurements, further increasing the volume derived from thick patches of relatively large trees for the interior. Based on the average volume per acre (i.e., 4100 cf/acre) and the required fuel volume (i.e., 112,000 cf), SEGA anticipates a harvest of ±30 acres of similar poplar stands for

the initial harvest. An extensive inventory process is planned as part of future timber sale requirements, which will quantify timber volumes in greater detail.

C. Inventory Specifications and Stumpage Fee

A variety of methods and classifications are used for selling different forest products. The board foot has been the historical standard unit of measure for timber heading to the lumber mill (Avery and Burkhart 2002, 114). Other volume measures are calibrated through various sampling techniques that provide the seller and purchaser a guide from which designated parcels could be targeted for predicted quantity and corresponding costs. Weight-scaling (i.e., measuring the weight per load) has also been a common method for determining the basis on which to apply the price per unit of particular logs in a transaction. This technique introduces a simple method of record keeping and ensuring accountability when consistently applied according to the applicable rules by trained personnel.

Weight-scaling was an original requirement within the GYL TSA; however, after investigating a host of scale options, SEGA requested an alternative method. To meet the outlined terms of certified scales and bi-annual inspections, SEGA would have had to absorb an expensive system (e.g., \$150,000) that currently does not exist in Galena. Therefore, GYL presented the following timber cruise requirements, which will be the basis from which stumpage fees are calculated.

All trees to be harvested within units approved by the landowner (GYL) must be measured using the variable plot radius sampling method outlined in the Timber Sale Agreement (TSA). Volume will be recorded in cubic feet, using Smalian's rule. A single basal area factor (BAF) shall be used in each unit; 20 or 40 square feet, depending on

which factor consistently identifies six or more trees in each plot. Species, diameter at breast height (DBH 4.5'), total height and estimated defect percentage shall be recorded for trees of 5" DBH or greater. Saplings (i.e., < 5", but > 2") will be measured to the same specifications, minus percent defect, within a fixed 1/250th acre plot (i.e., 7.5' radius) at the same point. Sapling volume, if harvested, will be included in the total volume.

Plots will be spaced in a grid pattern. Units sized 4 acres or less will have a minimum of 4 plots and units of larger size require enough plots to achieve a $\pm 10\%$ error estimate at two standard deviations. Additionally, a clearing limit width of 50 feet, 25 feet on each side of the centerline, will be enforced for all access routes outside of designated units. Trees cleared within route limits must be inventoried and included in total volume payment. Volume of material designated for firewood or saw-logs will be calculated separately. Outside boundaries of harvest units will be mapped by GPS traverse or through GIS software.

Stumpage Fees are segregated by species (e.g., birch, poplar, spruce) and use (e.g., Chip wood, firewood, saw-logs). All species used for chip wood cost \$15.81/ccf (i.e., 100 cubic feet). This rate holds true for all other uses of poplar. Birch and spruce firewood prices are \$22.22/ccf and \$28.70 will be charged for each 100 ccf of spruce trees suitable for saw-logs (i.e., > 10" dbh). Given these rates, SEGA estimates an initial advanced stumpage payment of \$18,000 for 112,000 cf of trees.

It is recommended that SEGA work with a qualified and experienced timber cruiser for professional performance and training on cruise specifications for the initial harvest seasons. This expense is estimated to be \$4000 annually. SEGA will request

that employees who receive training on appropriate methods be granted authority to perform future collection and deliver reports in-house, with continued cross-check and inspection by GYL's certified forester (CF). Approval of this component would lower future overall costs of production.

V. Fuel Supply Strategy

A. Land Ownership & Biomass Distribution

Estimates indicate the presence of 5,050,297 ccf (i.e., 7,820,609 dry tons) of biomass within the GWC. This material is distributed across a variety of land designations and ownership, including; Bureau of Land Management (BLM), US Fish & Wildlife Service (USFWS), US Military, Patented Native Allotments, regional and village Native corporations (i.e., Doyon Limited, Gana-A 'Yoo Limited), State of Alaska and City of Galena. Of these entities, the State of Alaska (37%), Doyon (23%, GYL (18%) and BLM (11%) account for 76% of the total acreage (i.e., 89% of biomass). 32% of the available acreage (i.e., 396,060 acres) harbors 80% of the total biomass (i.e., 6,246,738 dry tons), the majority (i.e., 90%) is located on lands > 10 miles from the village center (Stumpf 2012, 29-33).

It is recommended that SEGA engage with managing officials of each entity to explore future harvest potentials. Average tree density per acre increases the further one travels from the village core; however, access development, increased transportation costs and differing public opinion brings rise to several hurdles that will need to be negotiated in a collaborative forum. SEGA has embraced a crawl, walk, run

approach to implementation of a wide-range of components related to this project and aims to incrementally develop relationships throughout the GWC.

B. Gana-A 'Yoo, Limited.

1. Management Goals & Objectives

GYL was formed in 1978 to represent the interests of shareholders from four ANCSA villages (i.e., Galena, Koyukuk, Nulato and Kaltag) that chose to merge. In 1993, the Tanana Chief Conference Forestry Department composed a Forest Stewardship Plan for lands managed by GYL. Within this plan, three overarching goals served as the impetus for identifying objectives; “protect land and natural resources for the enjoyment, prosperity and well-being of present and future generations, maintain quantity and quality of subsistence uses and opportunities, and utilize forest resources to promote economic development in local communities and the corporation” (Gana-A 'Yoo Limited. 1993, 6). A ten-year action plan included objectives that aimed to increase the moose population, improve berry patches, harvest saw-timber, inventory and monitor forest resources, write individual and comprehensive resource management plans and improve accessibility. Subsistence activities took prominence over other potentials (Gana-A 'Yoo Limited 1993, 7).

As the cost of heat and power generation increased throughout the region, and federal and state programs began promoting renewable energy projects, GYL chose to update their stewardship plan to support development of wood-biomass use for schools, community buildings and residential heating in associated villages (Doig and Olsen 2012, 2). Therefore, 1993 goals remain with updated objectives that promote forests

that will become the foundation for a sustainable forest based business, enhance and conserve wildlife habitat, maintain water quality and aesthetic attributes, comply with Alaska Forest Practices Act and Regulations and restrict uses that reduce ability to manage lands for future commercial timber production and subsistence hunting for shareholders.

2. Timber Sale Area

GYL administers a total of 144,492 acres within the GWC, which contains 16% of the estimated total volume. These lands surround the village perimeter, making them more easily accessible and requiring less extensive route development to harvestable material. GYL has been incredibly supportive of the larger project goals and has been proactive in developing a 20-year Timber Sale Agreement with SEGA.

The sale area is positioned north of the airfield and encompasses approximately 4720 acres (Figure 7). The southern and western portions are bordered by minor sloughs that diagonally pass from southeast to northwest. Vegetation consists of early-successional species with distribution of uneven-aged stands.

The northern and eastern areas experience narrow tracts of land with mixed-coniferous and hardwood composition. Long swaths of seasonal wetlands and grass fields are dispersed throughout. A large slough extends the length of the far eastern reaches, serving as a clear border between the sale area and lands closer to residential parcels.

The sale area provides a prime location for several project elements to develop and mature into an efficiently organized strategy. The relatively easy access and close proximity to the utility site allows for minimal production costs during critical transition phases (i.e., while the City and school adjust from a diesel to biomass fuel supply). These qualities also reduce operational complexity, allowing SEGA an opportunity to grow into a dependable fuel supply entity and refine maneuvers for future harvest tactics.

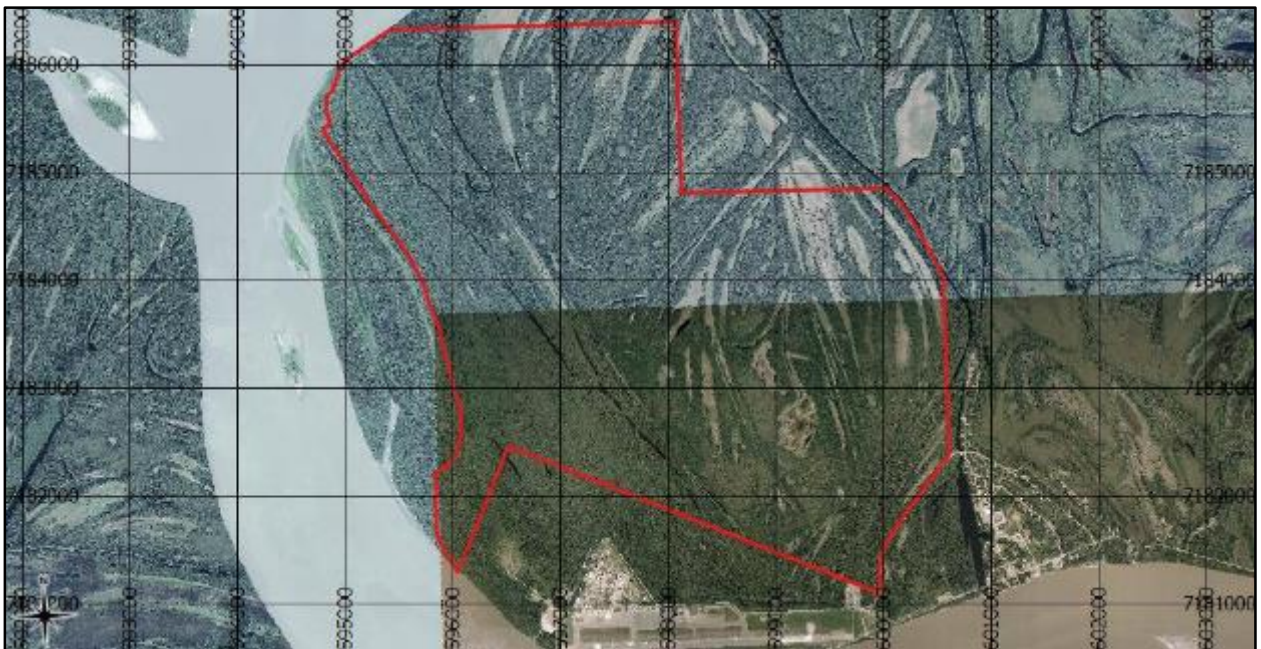


Figure 7 - Timber Sale Area marked with a red boundary line. Note the Galena Airbase to the south and New Town on the eastern border.

C. Forest Road Network

1. Early Route Considerations

Initial seasons will capitalize on dense patches of larger poplar located within two or three miles of the Galena airfield, limiting early costs related to constructing access routes. However, a network of temporary winter routes will need to develop within the GYL TSA area. Future timber sales are also likely on other GYL lands or with adjacent agencies; therefore, early development should not only complement near term harvest schedules (i.e., 2-10 years), but link to broad-scale strategic goals and objectives.

Early routes will be set on dry land or areas with vegetation; however, future access will likely use grass lake beds, sloughs and the occasional water crossing.



Figure 8 – Local Galena excavator that broke through the Yukon River ice (Doig and Olsen 2013).

Some waterbodies freeze solid and could serve as transportation corridors or landing sites. Deeper water bodies can be used to create ice road passages; however, unsuspecting weak ice or overflow conditions are challenges that beckon

extreme caution and require that diligent mitigation efforts be applied (Figure 8).

Ice routes can be created with a relatively simple procedure. An auger bit (e.g., 1-1/2" x 3') attached to a drill will compromise the ice layer and determine thickness. Water is retrieved from the hole via water-pump and applied to the ice surface from a delivery hose. Holes should be placed approximately 150' apart or as ice thickness

determines. Repeat process until desired thickness is achieved (Table 6). While ice routes can prove highly efficient, it is recommended that they be reserved for select situations.

Table 6 - Minimum ice thickness standards (Doig and Olsen 2013).

<i>Load (tons)</i>	<i>Required ice thickness (inches)</i>	<i>Distance between loads (feet)</i>
0.1	2	17
1	4	34
2	6	48
3	7	58
4	8	67
5	9	75
10	13	106
20	18	149
30	22	183
40	26	211



Figure 9 – Dozer frozen in the Nenana River, Nenana, AK.

2. Future Forest Access

Analysis of long-term spatial and temporal elements associated with road networks (e.g., harvest activities, terrain, ecological protection, social and cultural use areas) will provide a foundation from which area-based planning can proceed most effectively (Richards and Gunn 2000, 188). At all scales, appropriate consideration must also be given to maximizing volume, cost of production and revenue flows (Nelson, Brodie, and Session 1991, 104), while recognizing multiple criteria that support sustainable management of the forest environment (Hayati et al. 2013, 1768). This process calls for identification of critical factors inherent to route building (e.g., ground

slope, soil texture, susceptibility to erosion), weighing the importance of each, mapping, designing and assessing variations (Hayati et al. 2013, 1770).

Modeling software can complement a decision-making framework. Robinson, Duinker and Beazley (2010) suggest a two-part methodology. The first phase involves consideration of effects as they relate to road construction, presence and use. The second procedure consolidates information, determines the impact and importance, introduces mitigation strategies, implements selected measures and monitors effectiveness (Robinson, Duinker and Beazley 2010, 73).

SEGA strives to incorporate similar strategies and considerations into future forest access network activities. Initial planning sessions are scheduled with a State Area Forester, where conditions are less complex. However, consultation with a professional Forest Engineering firm may be advisable, if sale area warrants. Future organizational meetings and assemblies will serve as a forum for stakeholders and community members to assess variations, interject local knowledge and opinion and develop an agreeable access network.

Additional consideration should be given to options that could reduce the amount of local forest access. The Yukon River has served as a primary transportation corridor for previous episodes of harvesting in the region. Vast tracts of acreage with notable volumes of white spruce and birch expand south from the river's edge, upstream from Galena. Upon developing operational capacity, effort should be expressed toward the feasibility of utilizing local barge services to transport harvest equipment to units, perform winter logging and staging activities and return material via water route to Galena (Figure 10).



Figure 10 – Log-raft on the Yukon River.

D. Drying

The MC_{wb} of the final chip product is a key factor for determining annual harvest quantities. Felled material is likely to experience the most significant loss of MC_{wb} when decked in whole-tree form and left for at least one drying season. This will increase the potential biomass heat value, as well as decrease transportation costs associated with hauling green trees (i.e., high % of water). Also, material in log form will experience MC_{wb} loss, most significantly when arranged under a canopy in small stacks that allow air-flow and protection from precipitation (Filbakk, Hoibo and Nurmi 2011, 455).

Chipped material is capable of experiencing MC_{wb} losses when stored in small-piles or when follow-on procedures are implemented (e.g., aggravated turning or conveyor movement). However, storage of chips for long periods or in large volumes can present issues such as fungal and bacterial activity, uneven moisture content and dry-matter losses that decrease product value. Chipped material should be fed to the boiler system promptly upon processing (Filbakk, Hoibo and Nurmi 2011, 455).

In Galena, several drying experiments are underway. Future results will refine the procedures. However, based on the literature, local and professional knowledge and studies performed under similar conditions (e.g., Ft. Yukon Biomass Project) the following process has the potential to provide material at 40% MC_{wb} within one drying season and a further decrease of MC_{wb} given additional time (i.e., a second drying season). This method utilizes the specific equipment already acquired and expected to be utilized for this project, and described in Section VI.

Trees will be felled in the winter and stroked through the processor a minimum of one time. This action will remove limbs and compromise the bark; additional runs through the processor will further perforate, tear and remove the bark, exposing the wood beneath the cambium layer (Figure 11). Whole-trees will be cut to length (e.g., 20', 30, 40' segments) depending on individual tree height. Shorter logs will likely experience a greater loss of moisture, but longer logs are more efficiently chipped.



Figure 11 – Balsam Poplar samples in Galena, AK.

Logs will be stacked in piles sized to satisfy the grapple capacity of the skidder, which is approximately 12.5 ft² (tongs tip to tip) or 3.5' x 3.5' square. Piles will avoid obvious locations that threaten to accumulate moisture during the drying season and, as best as possible, be situated

on-top of slash material and other residual debris, reducing ground contact and risk of saturation or premature decomposition. It may be necessary to position dunnage logs

on the ground, perpendicular to the main pile, to avoid contact. Smaller piles will aid the drying process by reducing the quantity of logs stationed within the center of each heap. MC_{wb} loss is not expected during dark winter months or when outside air temperature is below 32° F.



Figure 12 – Interior view of a chip shed in Dry Creek, AK.

Log piles will remain within the harvest unit for one-drying season, at which time they will be transported to a decking site near the chip processing area. With the exception of first year boiler operations, logs will undergo a second drying season within these

larger stacks. Material will be processed through the chipper into an outside storage shed with a roof and open sides present to prevent exposure to precipitation, but encourage airflow (Figure 12). During early and late season operations, additional MC loss might occur for chips on the outside of the pile; however, material will likely be consumed within one month of chipping, which will complete the drying cycle.

The process of being able to dry logs in the field for one season is dependent upon being able to harvest more than one year fuel supply at a time. The initial harvest (1800 gt) must be transported and dried in the storage decks, so that chipped fuel can be made available when the boiler goes on-line. Therefore, an ideal situation would be to harvest a quantity that satisfies two annual heat requirements, which would provide

the initial load (e.g., 1800 gt at 40% MC_{wb}) and a second drying season for the next (e.g., 1500 gt at 30% MC_{wb}).

VI. Operational Harvest Plan

A. Equipment

A grant of \$500,000 was awarded to the City of Galena by the State of Alaska specifically for purchasing necessary harvest and

processing equipment. Despite

delays to the project inflicted by the 2013 Yukon flood event, the barge season saw the arrival of three pieces of machinery.

The harvester will fell, de-limb and stack trees, while the skidder pulls bunches to the roadside or landing. A self-loading truck will load logs, transport and unload in



Figure 14 – John Deere 748G-III Skidder



Figure 13 – Hitachi ZX200 with Waratah Processor

larger decks. A knife chipper will process logs into usable product. The harvester is a Hitachi ZX200 with a Waratah 622 processor head (Figure 13). A highly efficient machine capable of effectively felling trees between 4" and 22"

diameter. A John Deere 748G skidder with front blade and grapple will be able to assist in field transportation, limited route clearing and potentially be configured to perform necessary scarification measures (Figure 14).

A recently acquired self-loading truck will introduce several functions that increase efficiency (e.g., organized loading and unloading, create taller deck stacks, maneuver and transport material for processing) (Figure 15). Capable of hauling 20+ ton loads, the rig can accommodate logs 20-40' in length. The Bandit knife chipper can process a maximum of 14" diameter logs with a small feed-grapple and extended rear-delivery chute (Figure 16).



Figure 15 – Self-loading log truck (R.M.Fogle 2015).

A lease or contractor agreement will be developed for other necessary equipment or harvest functions (e.g., constructing access routes). A dozer will be used for sheering stumps, leveling soil, and positioning, smoothing or compacting accumulated snow. An excavator may be required for trails that transect areas consisting of larger diameter stumps and deeper root systems.



Figure 16 – Bandit M1400 Self-Propelled Chipper

B. Equipment Operators

Part-time and full-time employment opportunities will be made available with local priority. Because of the community's small size, there is a limited labor pool from which to hire specially trained operators for highly-technical equipment. Therefore, a robust training and test harvest must supersede any independent operations.

The initial training will be open for all interested candidates to become familiar with equipment, safety protocols and harvest standards. Of those who successfully complete the requirements, SEGA plans to hire 2-3 primary operators to fulfill a variety of functions distributed throughout each harvest season. It is important that employees not only demonstrate safe and productive performance, but also have the aptitude to become integrated contributors to the overall fuel supply system.

C. Harvest Practices

Best Management Practices (BMPs) will need to mitigate ecological impacts of harvest, apply appropriate reforestation activities and attempt to enhance conditions for a variety of forest values. SEGA intends to implement positive-impact logging strategies that will compliment disciplined monitoring and adherence to recognized protocols and regulations (i.e., the Alaska Forest Resources & Practices Act 2013 with 2015 amendments). These actions revolve around five critical functions, including; a) reduce physical effects of logging equipment, b) mitigate effects on residual trees, c) establish procedures that eliminate environmental impacts of pollution, d) avoid creating conditions that promote the unpredictable impacts of invasive species and e) carefully

consider areas of harvest, in order to decrease the potential effects of fragmentation (McEvoy 2004, 137-138).

All extraction activities will take place during the winter, in order to protect ground vegetation and reduce exposure of mineral soil. Entrance to harvest units will begin when soil frost depth meets or exceeds 6" or when snow accumulation provides adequate load bearing capacity (8-12") (Davis, 60). The wide-footprint and tracked-wheels of the harvester, accompanied by wide tires on the skidder, reduce ground pressure and soil compaction (MacDonald 1999, 51).

It is recommended that felling and skidding occur in the early-winter when the ground is frozen, but little snow has accumulated. This aids in reducing the potential of soil compaction, while assisting future regeneration. The tracks of the harvester and wide chained tires of the skidder will provide limited scarification disturbance (i.e., tilling) to low-pass areas within the harvest units. Individual stands are configured in random shaped patches covering 2-4 acres. This characteristic promotes short randomly distributed skid trails that position material for roadside retrieval, reducing the need for larger landings. Multiple-pass transportation routes will strive to occupy < 15% of the total area impacted with 10% as the ultimate goal (McEvoy 2004, 56). These areas are more likely to experience soil compaction and altered regrowth, due to thick snow trails that take longer to melt than surrounding areas. Careful mechanical site restoration may be required for heavily used routes and when deemed necessary to support regeneration (Lof, Dey, Navarro and Jacobs 2012, 827).

Temporary access routes and water crossings will be constructed in a manner that promotes natural drainage when compacted snow melts and avoids causing bank erosion and sedimentation that threatens future water quality. Water body crossings will be avoided when feasible; however, where required, right angle passages will be located to fit the topography and be located away from or upstream of bends (Division of Forestry 2011, 18). Slash material may be utilized to stabilize entrances or exits, but should not be to such an extent that material impedes flow rate (Wear, Aust, Bolding, Strahm and Dolloff 2013, 559). Travel during freeze-up and break-up will be avoided, in order to reduce potential formation of ruts. Closure markings will be erected to restrict off-road vehicle (ORV) use during warmer months that inflicts significant damage to vegetative layers and rutting (Davis, 60).

Avoidance of soil compaction further reduces potential damage to residual trees. Compressed fine-root systems or injury from soil shearing can allow entry of disease-causing organisms. Main stem injury from felled timber or equipment can introduce infection, reducing productive capacity and stem strength (McEvoy 2004, 137-138). Smaller stems (e.g., 2"-4" dbh) and other undergrowth (e.g., < 2") that impedes felling and stroke processing should be removed first (i.e., cut or driven over), as they can obstruct safe operations and damage equipment (e.g., rub or break hydraulic lines and fittings). In this situation, smaller stems may be added to larger bundles for later processing; however, when possible, residual damage to this vegetation should be avoided. Layout patterns should facilitate direct retrieval by skidder or log-truck. Rub trees that are later harvested can aid in more complex skid patterns (MacDonald 1999, 134).

Environmental impacts of petroleum, oil and lubricants (POL) can be minimized by handling in designated locations only with a ready spill-response kit on-site. Checks for leaks, worn hoses and loose-fittings will be part of daily pre-inspections. Fluid compartments are to be filled at the conclusion of each day, followed by post-preventive maintenance checks. Large quantities of POL will not be stored within the harvest unit; rather, a service-vehicle will transport bulk fuel (i.e., ~125 gallons) and associated tools and equipment.

The silvicultural system employed will involve clear-cutting qualified trees (e.g., between 4" – 14" base diameter) in small 2-4 acre patches. Stem-only harvesting (SOH) has been suggested to achieve maximum productivity from the dangle head processor and to retain biogeochemical attributes of slash residues within the harvest unit. In soils with low organic matter, whole-tree harvesting (WTH) has the potential to negatively impact nutrient exchange within upper-layers (Thiffault, Pare, Belanger, Munson and Marquis 2006, 700). Distributed slash material can further protect against soil compaction in low-pass areas (McDonald 1997, 15).

Trees with a base diameter > 14", but less than 22", will likely be harvested and processed for other products, because they are too large for the chipper feed-system. 22" diameter is the top-end limit of the dangle-head processor. However, lower stems of larger trees contain significant volume. Acquisition of an additional attachment could split 10-12' segments into widths suitable for chipping. Although rare, poplar cordwood could find a niche for community members. Appropriate lengths of large diameter segments could be dried and milled into lumber.

Riparian Zone buffer widths vary by water-body class designation. Back-sloughs and lakes require a 33' buffer, while large waterbodies (e.g., Yukon River) and salmon-rearing streams necessitate a 100' safeguard. Within harvest areas, trees larger than 22" will be retained, which may require retention of smaller merchantable timber to protect against damaging wind-throw, provide wildlife habitat between recently opened canopy, and to serve as seed-trees (Groot, Lussier, Mitchell and MacIsaac 2005, 53). Additional buffers and corridors will be retained, when applicable, to negate the potential effects of fragmentation (Potvin and Bertrand 2004, 50).

Balsam poplar are capable of natural regeneration from seeds, stump sprouts, root suckers and buried branches. Winter logging with tracked equipment is recommended for early season periods with little to no snow, because the activity inflicts limited disturbance to the top soil, which enhances root sucker propagation. This is a highly desirable species trait that reduces production costs (e.g., planting, scarification) associated with other species and ground conditions (e.g., white spruce, organic matter compositions) (Peterson and Peterson 1992, 30).

D. Harvest Operations

SEGA has obtained permission to cross State Department of Transportation (DOT) Airport property, in order to access GYL lands. With minor widening completed, these routes will serve as future entry and exit points. Thorough discussion and consideration of initial harvest locations have led to the decision that the training session and extraction of two years biomass be performed in the southwestern portion of this sale area. Several reasons led to this conclusion (e.g., high-volume poplar, low-personal use area, natural regeneration, close to utility).

Approximately 25 acres of poplar stands are dispersed in narrow swaths 1-4 acres in size. One mile of winter road will need to be constructed to access these units. An additional mile and a half may need to be placed, pending the results of scheduled ground truth timber cruises of the remaining volume needed. An aerial and map reconnaissance suggests sufficient volume in the 170 acre parcel further north, which could bring the total forest route distance to two and a half miles for the initial harvest season. Under this scenario, the furthest transport distance is approximately 4 miles.

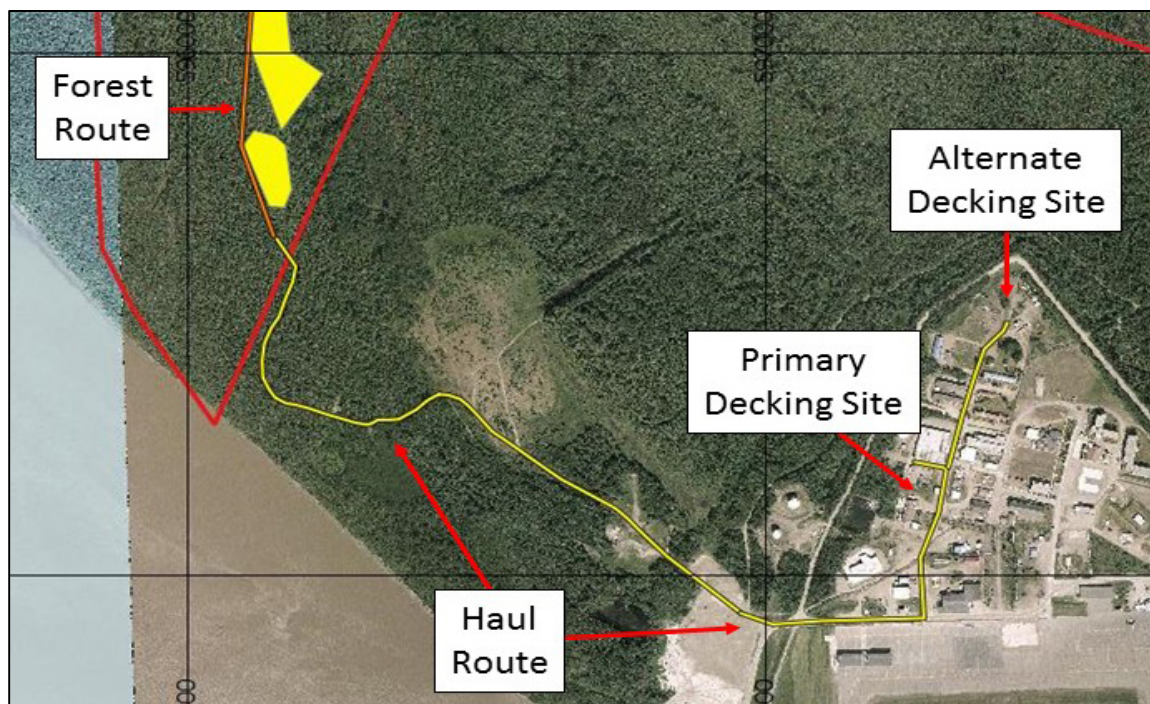


Figure 17 – Haul route from harvest units to decking sites.

The arrangement of smaller harvest patches allows initial road construction to capitalize on a single relatively straight route. Depending on stand size, the harvester may be able to position bundles roadside. The skidder will also retrieve bundles from the harvest unit and deliver them within reach of the log-truck on the roadside or to a larger landing, which would serve as a turn-around point for the log-truck. The quantity

of road constructed is dependent on the harvestable area and the required skidding distance. It has been recommended that skidding distances not exceed 1200', less is desired (Jeff Hermann personal correspondence). Therefore, this arrangement is intended to minimize road construction and distance traveled by the log-truck, while also reducing skid distances.

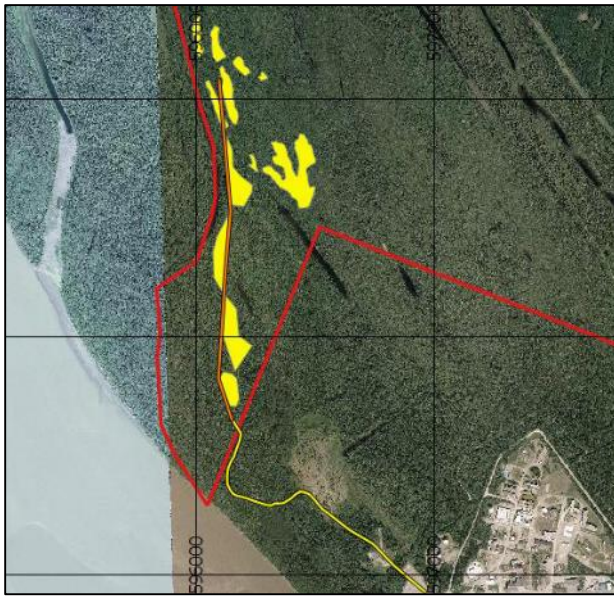


Figure 18 – Harvest units totaling ±25 acres, requiring 1 miles of forest road.

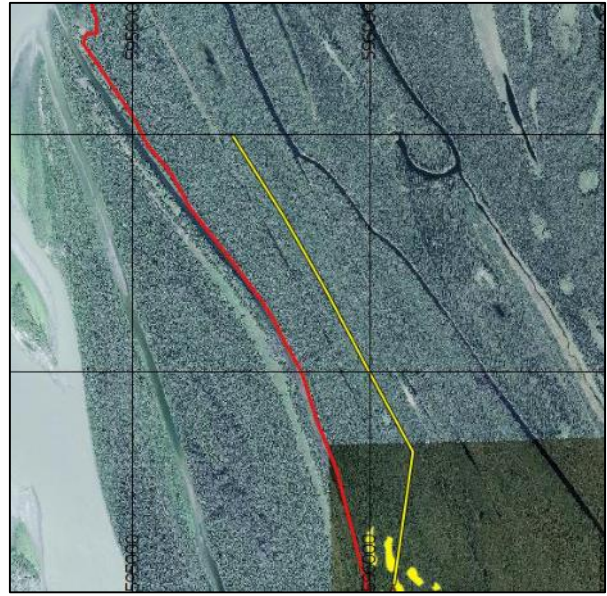


Figure 19 - 170 acres parcel that will require an additional 1.5 miles of route development.

Estimated skid-road density and spacing is needed within harvest units. Expressed as mile per square mile, road density is a function of dividing the total distance by the unit area (Picman and Pentek 2015). The result (e.g., 10 m) suggests an optimal spacing distance of 528' (i.e., 5280' divided by 10 m). This serves as an indicator for future road construction and identifies a planning variable that requires quantified data (i.e., quantity and distance of spur-trails). Optimal road spacing occurs when road construction cost is the equivalent to the variable skidding cost and the design minimizes all transportation costs (Sessions 2007, 24).

Routes will be constructed with a D6 Dozer or equivalent. The harvester will lead the procession with the dozer performing stump clearing, leveling and compacting snow. The operator can work independently of other activities and will aim to place access along an edge perimeter of the respective harvest patch, when feasible. With the given configuration of harvest units, this approach aids in creating a straighter haul road positioned to reduce skidding distances, without placing a high-use route, that may be used in subsequent seasons, through previously harvested areas. Larger stumps may require additional methods (e.g., excavator), if needed. It is estimated that the dozer will need to work the equivalent of 2.5 days a month (i.e., 12.5 days a season) to create and maintain 3 miles of road. This will be especially critical during initial stump removal and leveling for log transportation. An excavator is available from the City and is estimated to work the equivalent of 5 days a season, the majority during initial road development.

Following the previously outlined logging practices, the harvester will place processed logs in small decks suitable for the skidder grapple. Production of 5 gt per hour is the baseline conservative estimate, requiring 56 work days for 1800 gt. This is estimated to improve to as much as 10 gt per hour, as operator experience increases.

The skidder will position small decks along the roadside or gather at a landing. It is estimated that the skidder can produce approximately 13 gt per hour. This estimate assumes that the grapple, with a 12.5 ft² enclosed area (i.e., tongs tip to tip) at 80% capacity (i.e., ~ 3.2' x 3.2'), can grasp bundles of logs with 30' average length. The load volume is approximately 310 cf of stacked wood, which is reduced to 186 cf of solid

wood or 4.2 gt. Estimated average skid distance is 600' and average cycle time 25 minutes, providing 2.4 cycles per hour (i.e., 13 gt/hr).

The harvester and skidder activity will enable the log truck to retrieve loads with the grapple, transport to the decking site and unload. The self-loading log truck is capable of safely transporting approximately 20 gt, due to its size, age and recommended maximum load weight. For this season, it is assumed that the average load will weigh 15 gt, requiring 24 scheduled machine days (i.e., 8 hours) at 5 loads per day for 1800 gt.

Table 7 - Summary of productivity estimates and costs per equipment type.

	Harvester	Skidder	Chipper	Log Truck	Dozer	Excavator
Productivity (hr)	5 GT	13GT	5 GT	19.5 GT	0.2 mile	0.2 mile
Productivity (season)	1800 GT	1800 GT	1800 GT	1800 GT	3 mile	3 mile
Hr/yr	450	179	225	192	100	40
NPMH (\$/hr)	\$112.40	\$116.40	\$94.40	\$109.00	\$126.00	\$134.00
PMH (\$/hr)	\$154.00	\$182.00	\$160.00	\$177.00	\$234.00	\$194.00
\$/day	\$1,165.44	\$1,351.04	\$1,175.04	\$1,307.20	\$1,699.20	\$1,456.00
\$/gt or \$/mile	\$36.42	\$16.75	\$18.36	\$17.43	\$7,080	\$2,427
\$/1800 gt	\$65,556	\$30,157.14	\$33,048	\$31,373	\$21,240	\$7,280

Production estimates for all equipment are based on scheduled machine hours with 80% productivity (i.e., 8 scheduled machine hours (SMH) resulting in 6.4 productive machine hours (PMH) and 1.6 non-production machine hours (NPMH)), baseline labor wages (i.e., \$42 per scheduled hour, which includes employer costs), and \$5 per gallon for bulk delivered diesel. NPMH accounts for waiting or standing time. NPMH and PMH cost calculations differ in that NPMH fuel consumption and maintenance costs are

20% of PMH values. Additional variables are specific estimates per equipment type and activity (Table 7; Appendix D).

It is recommended that harvesting, skidding and route construction begin as soon as conditions allow. This will likely be between mid-October and the first of November, when daytime high temperatures average between the mid-20°'s F and begin to drop below 0° F at night. This period experiences little snow accumulation, allowing prime opportunity for the equipment to operate with reduced risk of incident (e.g., stuck in snow, striking stumps). During this period, 8 hours of daylight is conducive for the average scheduled workday (e.g., 8-12 hours). However, near the end of November, daylight hours reduce to < 5 hours and long cold snaps (e.g., < -20° F) are common. Logging activity will cease when temperatures are -20° F or colder.

Based on these considerations, it is recommended that the appropriate lighting equipment and safety protocols be incorporated that will allow for harvest operations during sunset hours. This requires training, budgeting and scheduling for an additional labor crew that would be able to capitalize on prime production periods. All felling and the majority of skidder work could be performed, prior to the darkest and coldest periods of winter.

In November, primitive routes will be clear of stumps and made ready for accumulating snow. It is recommended that route maintenance continue throughout the remaining winter months, as snow-depth increases and temperatures allow. During this initial year, low productivity is expected of newly trained operators; therefore, as conditions allow, harvesting and skidding will likely continue in December through March (Appendix A; Appendix B).

While it is important to remain flexible and capitalize on unforeseen harvest opportunities, it is recommended that production periods be consolidated during times when operations can be near continuous. Labor costs are a variable expense dependent upon operational hours. It might prove difficult to keep employees engaged when seasonal conditions do not allow consistent work schedules. Sporadic operating days held during times of limited productivity (i.e., limited daylight, continuous extreme cold) also have the potential to compound with increase maintenance costs. The result could quickly become cost prohibitive or catastrophic to operations, especially if a significant equipment malfunction occurs or operator gains employment elsewhere.

On average, January (-1° to -16°F) and February (5° to -14°F) are the coldest months. Daylight is limited between 5 and 8 hours per day. Average high and low temperatures in late-February begin to increase between 10°F and -10°F. March experiences a similar warming trend; although, late-February and all of March can easily experience peak lows of -30°F and colder. On the bright side, daylight hours drastically increase from > 9 to 12 hours. Due to the increased warmth and daylight, February and March will see the conclusion of felling and switch to a skidding and transportation emphasis (U.S. Climate Data 2015).

Forest routes exiting GYL lands connect to personal use trails and ultimately lead

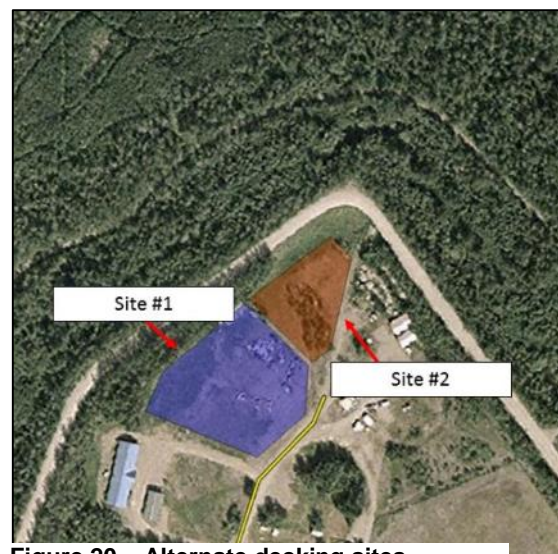


Figure 20 – Alternate decking sites.

to the west side of the former Galena Airbase. After crossing inside of the dike, loads will be delivered to one of two decking sites. The primary decking site is immediately adjacent to the current boiler utility with a three part footprint. The largest segment equals 140'x275', the others 40'x100' and 55'x105' respectively, for a total area of 480,000 cf when decks are stacked 10' high with the log-truck. It is estimated that 80% of the useable space (i.e., 384,000 cf) could contain the annual fuel storage requirement (i.e., 187,000 cf, which is 112,000 cf with 60% stacking factor applied) (Briggs 1994, 2).

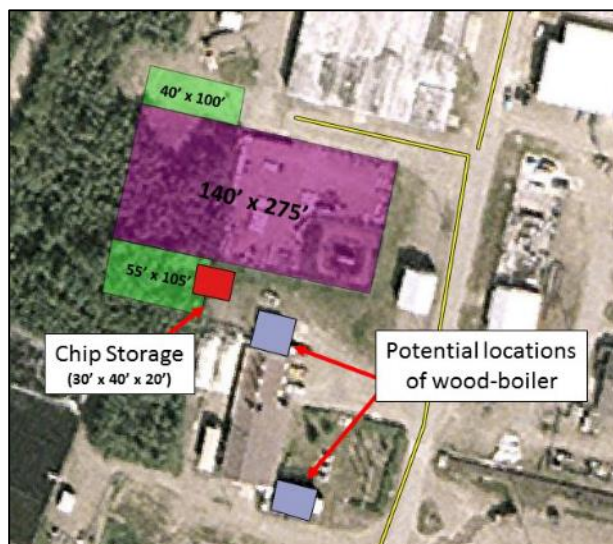


Figure 21 – Recommended primary decking site, chip processing and storage location with potential boiler locations.

The alternate decking sites are only 300 yards away to the north. With the same considerations applied as the primary sites, the 700,000 cf area (i.e., Site #1 490,000 cf, Site #2 210,000 cf) could store a two-year fuel supply and support chipping operations. However, at this time an unknown portion is reserved for other purposes (i.e., City rock storage).

How best to utilize these sites is dependent upon the final boiler location, chip bin system (e.g., chip vans, large stationary chip bin) and location of chipping operations and storage. Despite the uncertainties, it is recommended that the primary decking, processing and storage site be positioned as close to the utility as possible. Estimated chip production rates (i.e., 10 GT/hr, 620 cf solid wood, 1600 cf stacked chips) require 24 days to process 1800 Gt/yr. A wood to chip ratio of 1:2.5 has been applied to the

solid wood fuel requirement (i.e., 112,000 cf), which expands to an area > 280,000 cf/yr. Monthly chip use estimates range between 11,000 cf (i.e., September and May) and > 36,000 cf for the majority of the winter (i.e., November thru March) (Table 8).

Table 8 – Estimated wood fuel usage, based on Poplar at 40% MC_{wb}. Gross input and fuel oil data estimates from Gray Stassel Engineering 2015 (personal correspondence); Koontz 2013.

	Gross Input Heat (mmBtu)	Fuel Oil (gal)	Wood Fuel Input (mmBtu)	Wood Fuel (gt)	Solid Wood (cf)	Stacked wood (cf)	Chips (cf)	Ave gt/day	Ave gt/week	Ave cf chips/week
Jan	3388	2278	2991	310	19170	31950	47926	9.99	69.91	10822
Feb	2582	1737	2319	236	14601	24334	36502	8.42	58.95	9125
Mar	2717	1827	2443	248	15381	25635	38452	8.01	56.09	8683
Apr	1818	1223	1644	166	10254	17090	25635	5.52	38.64	5981
May	819	551	743	74	4570	7616	11424	2.38	16.66	2580
-	-	-	-	-	-	-	-	-	-	-
Sep	820	552	745	76	4681	7802	11703	2.52	17.64	2731
Oct	1749	1176	1582	158	9808	16347	24520	5.11	35.77	5537
Nov	2707	1821	2443	247	15269	25449	38173	8.22	57.54	8907
Dec	3073	2067	2763	279	17276	28793	43189	9.00	63.00	9752
Total	19674	13231	17673	1793	112567	185015	277523			

SEGA employees will use the log-truck to create decks and deliver logs to the chipper, as needed. The same individuals will process the material into an outside chip storage barn (i.e., pole-barn structure) with dimensions of 40'x40' and the capacity to create a stack of chips 20' in height (i.e., 32,000 cf) using the chipper. A bucket loader is available and may be needed to create this stack; however, at this time it has not been included in cost estimates. Assuming that 80% of the barn area (i.e., 26,000 cf) is usable, a > two-week supply would be on-hand throughout the heating season. Another option is to chip directly into an appropriately sized stationary chip bin. A 40'x20'x10' bin can hold 6400 cf, when an 80% usable space factor is applied.



Figure 22 – Sample of chips processed through the Bandit M1400.

The type of chips produced introduces additional operational considerations. The suggested KOB boiler can accept smooth chips sized with a maximum cross section of 2"² and length of 4.75" (i.e., G50 chip specifications) (KOB 2010, 5). The Bandit M1400 consistently produces chips within the stated parameters (Figure 22). High quality chips reduce the potential for material blockage (i.e., bridging) when delivered

through auger or walking-floor feed systems. However, chips may compact when stored for long periods of time and potentially freeze together. For example, chips stored in walking-floor vans have been reported to freeze to the bottom of the container. This scenario is very similar to the consequences experienced when a dump-truck is left with a load of gravel; the material may compact and stubbornly bind to the corners and floor. Should this occur in a chip van, the walking-floor may be inoperable and movement to a heated facility required (Jeff Hermann personal correspondence).

Based on these considerations, it is recommended that chipping into an outside storage barn be the primary method of delivering fuel to the City. Loads should be removed as daily operations occur (e.g., beginning and end of boiler operator shift) and chips not be stored for more than one month, in order to avoid significant compaction and large mass freezing. Chipping should take place an average of 2-3 work days a

month. Colder months may require more frequent chipping (e.g., twice a month) that can be performed between extreme cold periods (Appendix C).

The chipper is the project's single-point of failure. Meaning that if the chipper goes down there is no alternative to creating usable fuel for the wood-boiler. Short duration use on a daily basis throughout the season, regardless of temperature, provides increased unproductive machine and labor costs, preventative and scheduled maintenance requirements, and unnecessary risk of mechanical failure that results in the boiler going off-line.

Chipping into an appropriately sized storage barn increases productivity, reduces consequences of mechanical breakdown and establishes a clear point of sale between SEGA and the City. It is recommended that the final conceptual design include a simple and long-term cost effective system that delivers chips from the storage shed to the chip bin. For example, a City boiler plant operator could utilize a front-end loader with bucket (e.g., 4 yard bucket (~87 cf at 80% capacity) or equivalent to transport material to the chip bin. Chips at any location need to be stored under a roof, clear of precipitation.

E. Fixed and Operational Costs

Fixed costs associated with acquiring 1800 gt totals approximately \$150,000 (Table 9). Administrative functions include office rental, utilities, supplies and manager pay that total \$60,000. The insurance portfolio contains policies providing General Liability coverage with a Logging and Lumbering endorsement, Worker's Compensation with annual payroll adjustment, Pollution and Heavy-equipment policies at a cost of approximately \$43,000 annually.

Table 9 – Summary of Fixed Costs

Fixed Costs	
Administrative	\$60,000
Insurance	\$43,000
Performance Bond	\$10,000
Stumpage Payment (1800 gt)	\$18,000
Training & Pilot Harvest	\$15,000
Annual Timber Cruise	\$4000
Total	\$150,000

Other GYL TSA requirements include a one-time Performance Bond of \$10,000 that must be replenished each calendar year. A \$4000 expense has been budgeted for the timber cruises and an additional \$18,000 for the Advanced Stumpage Payment. The initial training session is forecasted to total nearly \$15,000. Continuing operator training and professional development line-items contribute an additional \$5000, under a routine operating calendar.

Maintenance is currently planned to occur in the City's repair shop. The chipper will be stored in-doors, potentially in the chip bin structure. This is yet to be determined. Other equipment will be stored outside or within a warehouse located north of the primary decking site (Figure 20). While adequate, locating a suitable maintenance and storage facility will add to the life expectancy of equipment, allow for thorough maintenance routines and potentially serve as a location for other activities (i.e., cordwood sales, milling, etc). SEGA is currently investigating a State DOT warehouse located on the former Air Base. Associated costs have not been included in this report.

	Harvester	Skidder	Chipper	Log Truck	Dozer	Excavator
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NPMH (\$/hr)	\$112.40	\$116.40	\$94.40	\$109.00	\$126.00	\$134.00
PMH (\$/hr)	\$154.00	\$182.00	\$160.00	\$177.00	\$234.00	\$194.00
Total hr	450	179	225	192	100	40
\$/day	\$1,165.44	\$1,351.04	\$1,175.04	\$1,307.20	\$1,699.20	\$1,456.00
\$/1800 gt	\$65,556	\$37,998	\$33,048	\$31,373	\$21,240	\$7,280
\$/gt/(\$/mile)	\$36.42	\$16.75	\$18.36	\$17.43	\$7,080	\$2,426.67

Table 10 – Estimated cost per NPMH and PMH.

Operational costs (i.e., \$197,000) are conservatively estimated and are likely to decrease over time for similar harvest scenarios, due to experience providing increased productivity. Initial capacity with the given fleet of equipment suggests dedicating nearly 1200 work hours for all pieces, distributed throughout each phase of operations (Table 10). Fuels, lubricants, maintenance and repair estimates have been given due diligence and allow for unpredictable mechanical issues; however, it is recommended that these numbers be reviewed closely and a secondary method of calculating repair and maintenance cost (e.g., estimated as percentage of depreciation) be used to check variance (Bushman and Olsen 1988, 14). Furthermore, repair of wheels and tracked components deserve their own expense lines, as these items have not been budgeted separately from the hourly maintenance estimates.

SEGA has assumed responsibility for the insurance and maintenance costs of the harvest equipment. Therefore, the current total equipment lease cost (i.e., \$67,000) might need to be adjusted. Further agreement between SEGA and the City can ensure lease funds will account for depreciation and applicable taxes and ultimately be applied toward the purchase of replacement equipment (Bushman and Olsen 1988, 7).

All costs identified herein are based on a single start-up harvest season and have developed with many uncertainties. If harvesting occurs for species other than

balsam poplar, additional scarification and planting expenses need to be included.

Future accounting should incorporate detailed prediction methods (e.g., Bushman and Olsen 1988; Miyata 1980) that account for inflation, which is complimented by accurate record-keeping and ground truth data. This will enable SEGA to more precisely forecast operating costs.

Table 11 – Total costs for 1800 gt.

Cost (1800 gt)	
Fixed Cost	\$150,000
Operational Cost	\$189,000
Total \$/1800 gt	\$339,000
\$/gt	\$188

Based on the predicted costs, the wholesale rate for the City of Galena would be \$188 for 1800 GT, which is the equivalent of \$308 for 1100 bdt. The total annual cost for the fuel wood supply is approximately \$339,000. The wood supplied will not meet demand during high load periods. The extra heat will be provided by burning diesel oil. It is estimated that 13,200 gallons (i.e., \$66,000 assuming \$5 per gallon) will be required to supplement the wood fuel during high loads. Therefore, the total annual fuel bill with wood fuel and converted diesel boilers will total \$405,000. Total fuel costs for a diesel only system would be approximately \$700,000 and consume 139,000 gallons of diesel.

Estimated operating costs for the heat plant is \$357,000, which brings the total cost for wood to \$762,000. The cost for a diesel only system is \$1,057,000. These figures applied to a predicted total heat output requirement of 14.7×10^9 Btu provide end user wholesale rate estimates of \$52 and \$72 mmBtu respectively, a difference of \$295,000 (Table 12).

Table 12 – Cost summary of heating system alternatives.

	Fuel Consumed (per/yr)	Fuel Cost (per/yr)	Plant Operating Cost (per/yr)	Total Cost (per/yr)	Total Cost (\$/mmBtu)
Current System	230,000 g	\$1,150,000	\$357,000	\$1,507,000	\$103
Diesel Only	139,000 g	\$700,000	\$357,000	\$1,057,000	\$72
Wood	1800 gt	\$339,000	\$357,000	\$762,000	\$52
Diesel	13,200 g	\$66,000			

VII. Conclusion

In approximately two years, diesel reserves left by the Air Force will run dry. Without the wood-boiler installation and much needed utilidor upgrades, the City of Galena is faced with ordering 230,000 gallons of fuel at a price of >\$1 million dollars annually. At \$5 a gallon, GCSD would be faced with a heating bill for GILA that is at least three times the current rate. SEGA is preparing for the inaugural harvest season and aims to extract at minimum a one-year local wood fuel supply (i.e., 1800 gt of balsam poplar) from the Native village corporation, GYL. In the new district heating system, a wood-boiler will provide approximately 90% (i.e., 17.7×10^9 Btu) of the total annual input requirement (i.e., 19.6×10^9 Btu). In order for poplar to provide sufficient

heat value in acceptable quantities and land area (i.e., ± 30 acres), MC_{wb} needs to reach 40% or less. Specialized harvest equipment will engage in an operational supply chain that utilizes seasonal winter roads for log transport to storage and ultimately through a chipping process.

SEGA can introduce support that aims to stabilize Galena's main economic contributor (i.e., GCSD), create local employment opportunities, promote high quality educational services and utilize local renewable fuel sources. Like many villages throughout rural Alaska, Galena values community and will persevere, due to the populations balance of resiliency and adaptive-capacity in challenging conditions (e.g., flooding, fires, and environmental extremes). This can be observed through multiple convictions (e.g., quality education, traditional and subsistence activities based on healthy forest processes, local self-reliance, economic stability). Public involvement in the decision-making process is key to developing a plan that allows efficient delivery without compromising the quality of life present within a unique rural lifestyle.

Providing the primary heat for the GILA campus with local fuel will be a collective achievement for Galena and stands to serve as a model for other villages throughout the interior of Alaska. Not only in terms of economic benefits, but also with respect to the social, cultural, ecological and ethical aspects involved. The project is an opportunity to reflect upon how communities can use various forms of capital (e.g., financial, social, human) to implement positive contributions. Offerings that provide multiple benefits and purposes, but also serve as physical examples that forthcoming generations may emulate. Under different settings, wood-energy may not be the answer, but renewable power is. Armed with a paradigm that seeks equitable solutions

for all concerned, future leaders and community members will be better positioned to apply balanced strategies appropriate for their conditions. It is a unique blend of these elements that will ultimately provide sustainable energy.

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IX. Image Citations

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Figure 2 – Google Earth. 2013. "Galena's position along the Yukon River." Accessed June 7, 2014.

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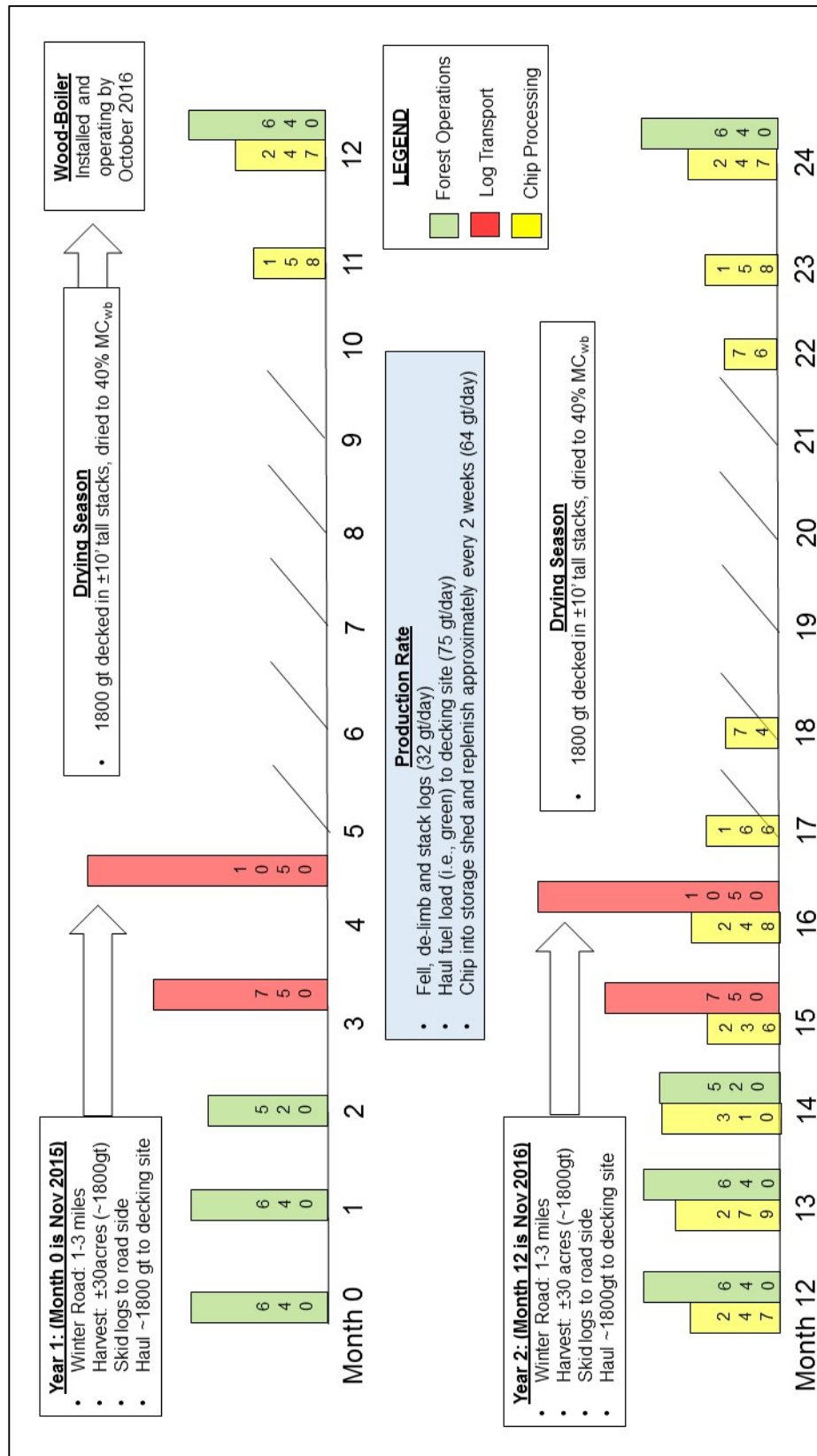
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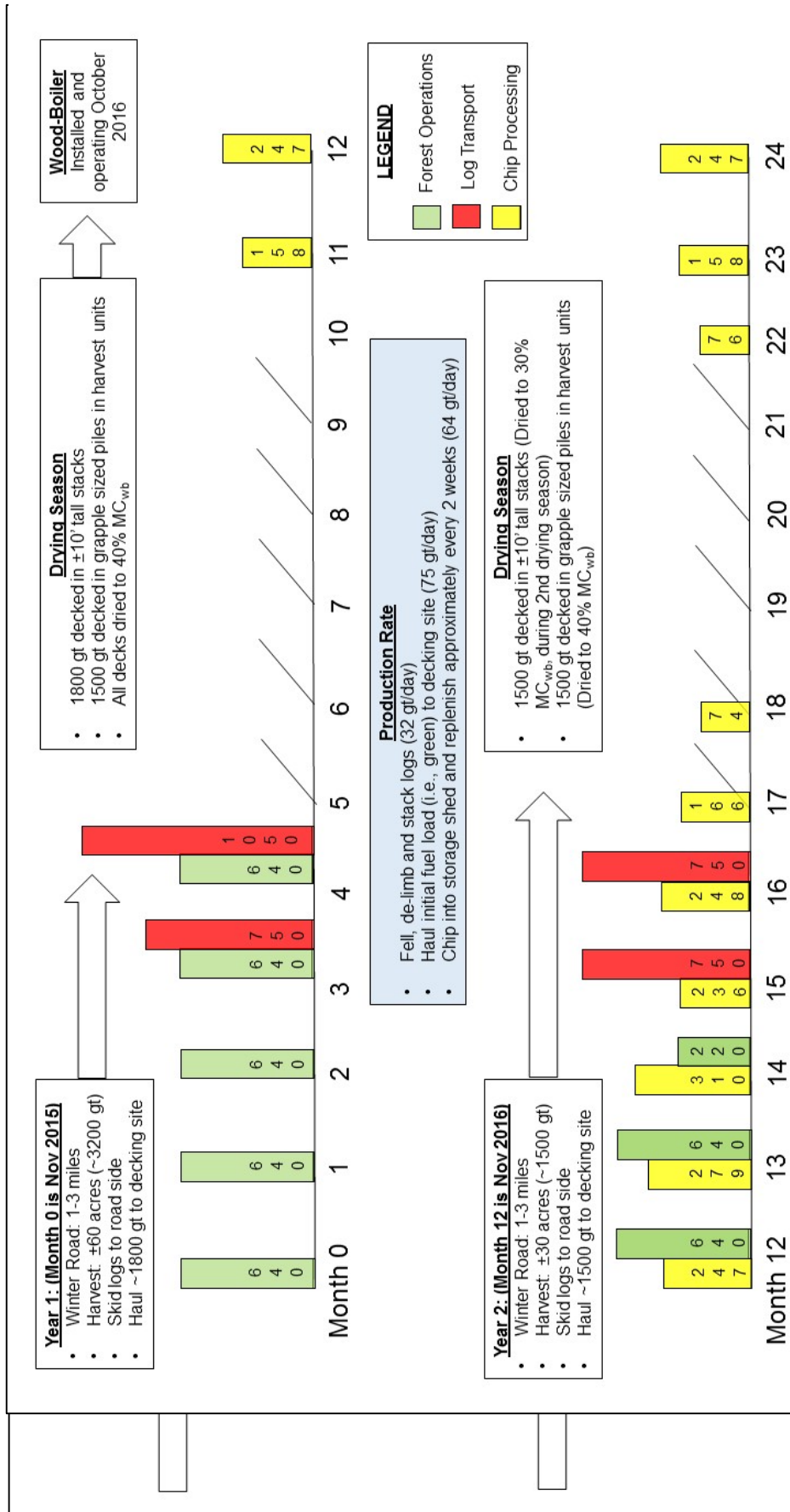
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X. Appendices

Appendix A – SEGA Harvest and Chip Supply Plan for extracting one-year of fuel each harvest season.



Appendix B - SEGA Harvest and Chip Supply Plan for extracting two-years fuel in one harvest season.



Harvester		Skidder		Chipper		Log-truck		Dozer		Excavator	
Scheduled Machine Hours (SMH), Non-Production Machine Hours (NPMH) & Productive Machine Hours (PMH)											
Total SMH hr/day	8	8	8	8	Total SMH hr/day	8	8	Total SMH hr/day	8	8	8
NPMH hr/day	1.6	1.6	1.6	1.6	NPMH hr/day	1.6	1.6	NPMH hr/day	1.6	1.6	1.6
PMH hr/day	6.4	6.4	6.4	6.4	PMH hr/day	6.4	6.4	PMH hr/day	6.4	6.4	6.4
Production											
gt/hr	5	13	10	10	gt/load	15	15	mile/day	1.2	1.2	1.2
gt/day	32	81	64	64	load/day	5	5	total/mile	3	3	3
gt/week	160	403	320	320	gt/day	75	75	total/day	2.5	2.5	2.5
gt/month	640	1612.8	1280	1280	gt/week	375	375	total day season	12.5	12.5	5
chip cfi/hr	-	-	621	621	gt/month	1500	1500				
chip cfi/day	-	-	3975	3975	bdt/day	45	45				
bdt/day	19.2	48.384	38.4	38.4	bdt/week	225	225				
bdt/week	96	241.92	192	192	bdt/month	900	900				
bdt/month	384	967.68	768	768							
Labor											
Labor (\$/hr)	\$42.00	\$42.00	\$42.00	\$42.00	Labor (\$/hr)	\$42.00	\$42.00	Labor (\$/hr)	\$42.00	\$42.00	\$42.00
Fuel and Lubricants											
PMH (gal/hr)	6	12	12	12	PMH (gal/hr)	12	12	PMH (gal/hr)	24	12	12
NPMH (gal/hr)	1.2	2.4	2.4	2.4	NPMH (gal/hr)	2.4	2.4	NPMH (gal/hr)	4.8	2.4	2.4
PMH (\$/hr)	\$30.00	\$60.00	\$60.00	\$60.00	PMH (\$/hr)	\$60.00	\$60.00	PMH (\$/hr)	\$120.00	\$60.00	\$60.00
NPMH (\$/hr)	\$6.00	\$12.00	\$12.00	\$12.00	NPMH (\$/hr)	\$12.00	\$12.00	NPMH (\$/hr)	\$24.00	\$12.00	\$12.00
Maintenance and Repair											
PMH (\$/hr)	\$22.00	\$26.00	\$22.00	\$22.00	PMH (\$/hr)	\$25.00	\$25.00	PMH (\$/hr)	\$15.00	\$15.00	\$15.00
NPMH (\$/hr)	\$4.40	\$5.20	\$4.40	\$4.40	NPMH (\$/hr)	\$5.00	\$5.00	NPMH (\$/hr)	\$3.00	\$3.00	\$3.00
Rental Cost											
Rental cost (hr)	\$60.00	\$58.00	\$36.00	\$36.00	Rental cost (hr)	\$50.00	\$50.00	Rental cost (hr)	\$57.00	\$77.00	\$77.00
Total Rental cost	\$27,000.00	\$10,357.14	\$8,100.00	\$8,100.00	Total Rental cost	\$9,600.00	\$9,600.00	Total Rental cost	\$5,700.00	\$3,080.00	\$3,080.00
Work Hours and Cost											
PMH \$/hr	\$154.00	\$186.00	\$160.00	\$160.00	PMH \$/hr	\$177.00	\$177.00	PMH \$/hr	\$234.00	\$194.00	\$194.00
NPMH \$/hr	\$112.40	\$117.20	\$94.40	\$94.40	NPMH \$/hr	\$109.00	\$109.00	NPMH \$/hr	\$126.00	\$134.00	\$134.00
Total/day	\$1,165.44	\$1,377.92	\$1,175.04	\$1,175.04	Total/day	\$1,307.20	\$1,307.20	Total/day	\$1,699.20	\$1,456.00	\$1,456.00
hr/1800 gt	450	179	225	225	hr/1800 gt	192	192	hr/1800 gt	100	40	40
day/1800 gt	56.25	22.32	28.125	28.125	day/1800 gt	24	24	day/1800 gt	12.5	5	5
Total \$/1800 gt	\$65,556.00	\$30,757.14	\$33,048.00	\$33,048.00	Total \$/1800 gt	\$31,372.80	\$31,372.80	Total \$/1800 gt	\$21,240.00	\$7,280.00	\$7,280.00
\$/gt	\$36.42	\$17.09	\$18.36	\$18.36	\$/gt	\$17.43	\$17.43	\$/mile	\$7,080.00	\$2,426.67	\$2,426.67
Fixed Costs											
Operating Costs	\$189,253.94										
Total \$	\$339,253.94				Total Rental Cost	\$63,837.14					
Cost (gt)	\$188.47				Total Volume	1800					
Cost (Bdt)	\$308.41										