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Plastic Wood and Alternative Materials for Trail Structures

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INTRODUCTION

Historically, trail structures and boardwalks have been constructed of wood found in the local area. The Forest Service, an agency of the U.S. Department of Agriculture, has thousands of linear feet of puncheon boardwalks that have deteriorated and need to be replaced. Some sites are in the third generation of puncheon, and there is a lack of onsite materials. Some of the material is treated wood and split western red cedar, which has a useful life of 40 years at best. There is now a concern about using treated wood in wetlands and the exposure of trail workers to hazardous chemicals. Forest staffs want to use material that has greater longevity, is more environmentally friendly, and is safer to install and maintain. While the initial cost of alternatives to traditional woods may be more expensive, the cost of maintenance and length of life may prove to be less cost effective over time.

With the advent of new materials, other options are now available. New technology, such as recycled plastic lumber, plastic (polymer) reinforced with fiberglass (RFP), aluminum, and rubber lumber, is being used. For wood applications, tropical hardwoods are being used with great success; for treated lumber, there are environmentally friendly wood preservatives that can extend the life of a project.

This guide is written for anyone exploring alternative materials for new trail structures or replacing existing trail structures. It includes types of materials available, the advantages and disadvantages of each material, and examples. There is a Web link for additional information on structural elements of a trail. Wood treatment alternatives to chromated copper arsenate (CCA)-treated wood also are discussed.

Eight case studies are included in appendix A. Information on the Recreation Opportunity Spectrum (ROS) and the “Built Environment Image Guide” (BEIG) are included in appendix B.

BACKGROUND

Almost every material used for a trail structure requires annual maintenance to remove debris and water and increase longevity. While no material lasts forever with little or no maintenance, there are materials that will improve the life and quality of a project if maintained and detailed to shed water. Each material has the potential to minimize maintenance issues. However, there needs to be a balance between specific project requirements, regional product availability, and recycling options. Some questions to ask when selecting material for the project application are:

- ❑ What is the initial cost?
- ❑ What is the maintenance effort and cost?
- ❑ What is the length of service life?
- ❑ What color is best suited for the application?
- ❑ What recycling options are available and convenient?
- ❑ Does the site have severe environmental conditions that make traditional lumber maintenance demanding?
- ❑ Is site installation unusually difficult, making a 30- to 50-year life desirable?
- ❑ What is the proximity to the materials being considered? Is there a suitable local source?
- ❑ Are products available that use only polyethylene with minimum additives or wood fiber? These products have the potential for being recycled.
- ❑ Are products available that use only 100 percent post-consumer ingredients? Many urban areas have recycling centers that offer polyethylene resins for local manufacturing use. If a resin/wood product must be used for the sake of appearance, find a manufacturer that uses local reclaimed wood products. See: <http://extension.ucdavis.edu/unit/green_building_and_sustainability/pdf/resources/how_green.pdf>.

STRUCTURAL ELEMENTS OF A TRAIL

Structural elements of a trail, such as elevated boardwalks, bridges, and retaining walls, must be designed by a qualified engineer or architect. This is to protect the public from injury, as well as to protect the Forest Service from liability. Plastic lumber is sized like wooden lumber, but under stress it behaves much differently. It can be used in structural applications, but it must be engineered according to its own structural properties.

The 2006 “Structural Grade Plastic Lumber Design Guide,” produced by McLaren Engineering, lists the current ASTM (American Society for Testing Materials) test methods for plastic lumber and gives the factors and formulas to be used when designing a structure with plastic lumber.

RECYCLED PLASTIC LUMBER

Recycled plastic lumber (RPL) is a wood-like product made from recovered plastic or recovered plastic mixed with other materials. It can be used as a substitute for softwoods, tropical hardwoods, rubber, or aluminum for decking materials on boardwalks. Recycled plastic can be worked like wood: it can be sawed, drilled, nailed, screwed, bolted, and painted. The thermodynamic properties of plastic—how much it expands and contracts in the heat or cold—are quite different from those of concrete, steel, or wood, the materials that would normally be used with recycled plastic (Steinholz and Vachowski 2007).

Figure 1—Recycled plastic lumber example.

Broadly speaking, there are four kinds of RPL:

- High- and low-density polyethylene.
- Wood-plastic composites.
- Fiber-reinforced polymers.
- Polyvinyl chloride.

High-Density Polyethylene and Low-Density Polyethylene

This type of recycled plastic lumber consists of up to 95 percent high-density polyethylene (HDPE), which is the same material used to make plastic milk jugs. Linear low-density polyethylene and low-density polyethylene (LDPE) also are used. Polyethylene is one of the most highly recycled and recyclable plastics, since large volumes are available that are reasonably clean and are separated easily from waste streams.

HDPE is used for decks and boardwalks. Companies are striving to make the materials more color-fast and ultraviolet (UV) stable. It is nonabsorbent, well suited for decking, decay resistant, and can have a 50-year warranty.

Although plastic tends to be slippery, the surface can be textured to help with the slipperiness. However, HDPE plastic lumber does not have the same load-bearing capacity as wood and should not be substituted in applications calling for wooden load-bearing components.

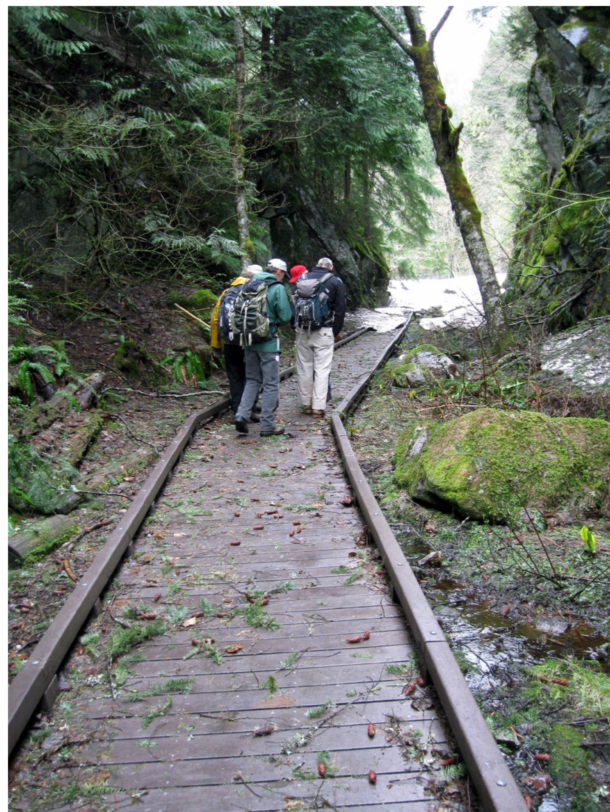

Figure 2—Forest Service Region 6 Iron Goat Trail, made of 100 percent HDPE RPL, installed in 2004.

Wood-Plastic Composites

This type of material generally contains 50 to 60 percent wood flour with plastic (often polyethylene), and additives that improve processing and performance comprise the balance. The wood stiffens the plastic and reduces expansion with temperature changes. When selecting RPL, ensure that the mix contains a preservative. Without a preservative, composite lumber can decay. When drilled or sawed, the shavings do not decompose. This problem can be resolved by drilling or sawing over a large plastic sheet and then disposing of it appropriately (Steinholz and Vachowski 2007). Overall, mixing biological and synthetic products results in a product with limited recycling options because the pure biological material cannot be reclaimed from the product. These materials can have a long service life (30 to 50 years) and low maintenance costs.

Figure 3—Wood composite example.

A wood-plastic composite provides good traction because it has greater surface roughness. It is available in many colors, and although it does not require painting, it can be. It does not require waterproofing or staining.

Wood-plastic composite lumber does not have the same load-bearing capacity as wood and should not be used in such applications because it lacks wood's sufficient stiffness and strength. It is less flexible than other plastic lumber and can expand and contract with the moisture content of the wood component.

Fiber-Reinforced Polymers

To improve rigidity or strength, some plastic lumber producers reinforce the primary plastic resin with other materials, such as fiberglass or polystyrene. This type of material contains 75 percent post-consumer HDPE and 95 percent total recovered material (70 percent recycled plastic and 30 percent fiberglass).

Fiberglass added to plastic makes the plastic much stronger than wood, and it has greater strength and stiffness for structural applications, such as joists, posts, girders, sea walls, piers, and docks. The highest grades of fiber-reinforced polymers (FRP) are approximately four times stiffer than the other grades of plastic lumber. These boards are the choice when free spans beyond the capability of the other grades are required. It is most commonly used as the understructure in deck or boardwalk construction.

Figure 4—Fiberglass-reinforced plastic lumber example.

Unlike treated lumber, FRP is nontoxic and nonleaching. It is colorfast and UV stable, available in many colors, nonabsorbent, does not require waterproofing or staining, and can have a 50-year warranty. It is less flexible than wood, and its increased weight may be reflected in higher shipping and onsite construction costs. It is non-renewable and petroleum based.

Fiberglass-reinforced plastic or polystyrene-polyethylene blends are used for structural support and may be preferable to products such as pressure treated wood. The structural grade plastic lumber is of superior strength to other plastic lumber and reduces the expansion and contraction properties common to plastic wood. For more information, see: <http://www.fs.fed.us/t-d/php/library_card.php?p_num=0623%202824> and <http://205.153.241.230/P2_Opportunity_Handbook/7_I_A_11.html>.

Fiberglass composites are more difficult to recycle. These composite materials are associated with greater health hazards during their lifecycles. Workers are advised to wear a properly fitting National Institute for Occupational Safety and Health-approved dust mask and protective gloves when handling them because they can cause skin irritation to people who are sensitive to fiberglass.

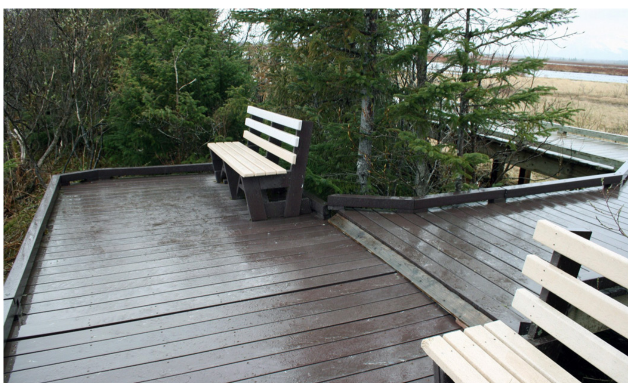

Figure 5—Alaska boardwalk.

Figure 6—Alaska boardwalk shows a combination of plastic wood with natural wood.

Polyvinyl Chloride

This material, commonly known as vinyl, is unique in that its composition is at least 50 to 60 percent chlorine (salt is used to create the resin that makes up polyvinyl chloride (PVC) and ethylene (from natural gas) and has a higher density than many plastics. It takes about 20 percent less energy to produce than other plastics.

There are concerns about toxic hazards in its lifecycle, and fiber-reinforced and mixed composite RPL are more difficult to recycle (Thornton 2002). See the Healthy Building Network homepage at: <http://www.healthybuilding.net>. Personal protective equipment is required when working with PVC. It has a limited thermal capability and is less flexible than wood.

PVC is highly durable, will not rot or corrode, does not require painting, and is recyclable. It is naturally fire resistant since chlorine has excellent inherent flame retardant properties. It is colorfast, stain resistant, nonabsorbent, and ultraviolet (UV) stable if appropriate additives are used. It is well suited for support structures.

Figure 7—PVC lumber example.

ALTERNATIVE MATERIALS TO PLASTIC LUMBER

North American decay-resistant woods, such as redwood and cedar (note: heartwood from eastern and western red cedar and redwood is decay resistant, but the sapwood is not), pine, spruce, and some fir, has an initial lower cost than plastics. Heartwood is more durable in exposed applications compared to sapwood when exposed to conditions that favor decay (Forest Products Laboratory 2000). “Only heartwood has significant resistance, because the natural preservative chemicals in wood that retard the growth of fungi are essentially restricted to the heartwood” (Forest Products Laboratory 2000). Wood weathers and changes color and requires periodic maintenance for best performance and service life. It requires staining to maintain the desired color. Wood must be replaced at some point and varies with exposure and maintenance. These softwoods cost less than other materials and have excellent strength and spanning characteristics. Maintenance costs over time can offset the initial cost savings.

Tropical hardwoods are harvested mainly from South America and are priced comparably to plastics. These tropical hardwoods are extremely strong and dense. They weather naturally if left untreated, are a far more natural look in the forest setting, and can last for more than 50 years. Some are rated class A for fire resistance and can be used structurally, unlike most plastics. Tropical hardwoods can be excellent choices for decking and trail applications.

If you want to use tropical hardwoods that are sustainably harvested, consider purchasing them from forests that are sustainably managed by the Forest Stewardship Council (FSC) and the Tropical Forest Foundation (TFF). See appendix B for additional information on the FSC and the TFF.

Wood is rated on the Janka Hardness Scale (see appendix B). Tropical hardwoods are rated very high on the Janka scale compared to the more common woods. Lapacho, or Ipe (pronounced ee-pay), is one of the hardest woods on the Janka scale. For example, Ipe has a rating of 3,680 on the Janka scale—three times harder than oak, which is rated about 1,200 on the Janka scale.

Ipe, Portuguese for “hardwood,” is also known as Ironwood, Brazilian Walnut, Pau Lope, or Papacho. It is a tropical hardwood in the teak family; very stable, dense, and durable; and naturally resistant to decay, wet conditions, and insect infestation. Ipe weighs approximately 65 pounds per cubic foot and sinks in water (Forest Products Laboratory 2000). It is rated class A for fire resistance.

Figure 8—Ipe wood example.

Figure 9—Bridge made of Ipe wood.

Figure 10—Picnic table example.

To avoid problems after installation, check the wood prior to construction with a moisture meter to ensure dryness. If the wood is not dried properly, the wood will check, crack, and warp over time, and the cracks can have very sharp edges. Sawing is more difficult than for the North American softwoods and most composites. Installers should use carbide-tipped cutting tools, keep the edges sharp, and always predrill for screws (Frechette 1999).

Because the wood is so strong, the joists that support the boards can be placed farther apart and the boards can be thicker, or the joists can be placed closer together and the boards can be thinner.

If the original color is desired, maintenance recommendations are to coat it annually with a semitransparent UV-blocking stain. If left to weather naturally, it turns a silver-gray color similar to teak.

Other tropical hardwoods also are available. For example, Tualang (Red or Yellow Balau), sold under the name of Mangaris™, is a tree that grows in Indonesia. It is extremely hard, clear grade, tight-grain, decay resistant, and kiln dried; it may be stain-finished or allowed to weather to a silver-gray color. It is rated 1,624 on the Janka scale.

Another example of a tropical hardwood is Tigerwood, found mainly in Brazil, Paraguay, and Uruguay. It is a boldly striped wood in a wide range of colors, has a dry hardness of about 940 on the Janka scale, can cause contact dermatitis, and requires carbide-tipped blades for sawing.

Rubber lumber consists of 60 percent recycled tires and 40 percent recycled plastics (mixture-specific grade). It is UV resistant because the mix contains tires that contain carbon black, which is a reinforcing agent used as a pigment and UV absorber in rubber products. The addition of carbon black to the polymer will usually absorb most UV radiation (Mitsubishi Chemical). Rubber lumber primarily is used for pool and patio decks, trailers, and so forth, but can be used for other applications, such as decks, docks, and marinas. It can be ordered in custom colors—gray and terra cotta—in addition to black.

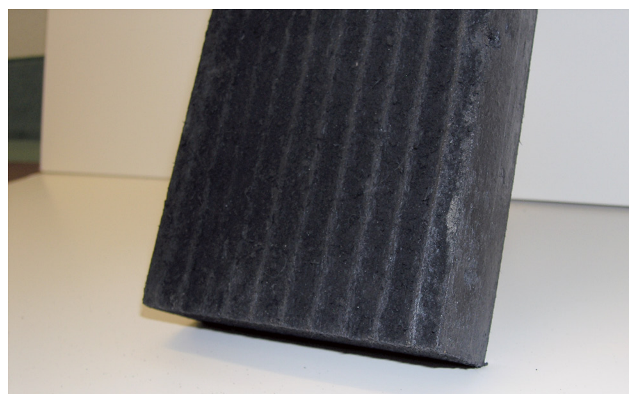

Figure 11—Rubber lumber example.

Rubber lumber is available in three different surfaces: slick, traction, and diamond pattern. It is good in cold and wet weather and is nonskid if traction grooves are added. It is insect resistant and impervious to moisture and mildew. Rubber lumber does not expand and contract, it is manufactured using recycled material, and is maintenance free. There is a 20-year limited warranty on the material.

It cannot be used for structural applications. The black color is hot in summer and gets softer in the heat. One company charges an up-charge of 25 percent for a color other than black; lighter colors are cooler than black (Rumber Materials, Inc.).

Aluminum is commonly used for structural and framing applications. It also is available as decking in standard plank with spaces, and with tongue-and-groove joints to make a watertight deck. It has been used for bridges and boardwalks (although not as often), since the material is not as natural looking as wood or wood-like products. However, some companies may have a wood-grain aluminum decking that is manufactured in several different wood-grain colors.

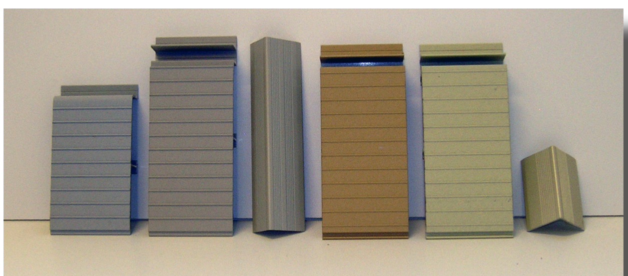

Figure 12—Aluminum decking material.

Aluminum is maintenance free and environmentally friendly; is available in colors; is cool, and nontoxic; can be used for structural applications and is easy to install; will not splinter, crack, or warp; and is nonskid with a textured coating. While it may not be an appropriate look in some forest settings, it does carry a Class A fire rating. Although it has a higher initial cost, it also has a 25+ year warranty.

WOOD PRESERVATIVES AND COATINGS

Chromated copper arsenate (CCA) is a chemical wood preservative containing chromium, copper, and arsenic, which protects wood against deterioration due to termites and fungal decay. The U.S. Environmental Protection Agency (EPA) <http://www.epa.gov> has classified CCA as a restricted-use product, primarily for industrial applications. CCA has been used to pressure-treat lumber since the 1940s. Since the 1970s, the majority of the wood used in outdoor residential settings has been CCA treated. Pressure-treated wood containing CCA is no longer being produced for use in residential settings due to health and environmental concerns about arsenic leaching out of the wood. Because new methods of treating wood are now in the marketplace for nonindustrial applications, CCA is permitted and continues to be sold to treat wood for many industrial, commercial, and agricultural uses. It is not recommended for picnic tables, benches, decking, railings or railing posts, or anywhere there could be possible skin contact. It can be used for structural applications where skin contact is not an issue. Typically, treated lumber is used for the undercarriage and posts because it is very durable, cost effective, and readily available.

The EPA Web site provides general information about CCA and these alternatives. Visit: <http://www.epa.gov/oppad001/reregistration/cca/pressuretreatedwood_alternatives.htm>.

Further discussion about preservatives can be found at the Forest Products Laboratory at: <http://www.fpl.fs.fed.us/rwu4723/preservation_faqs/types.html>.

The Missoula Technology and Development Center publication titled “Preservative-Treated Wood and Alternative Products in the Forest Service,” has a section that discusses alternatives to treated wood. See: <http://www.fs.fed.us/t-d/pubs/pdfpubs/pdf06772809/pdf06772809dpi300.pdf>.

The National Sustainable Agriculture Information Service has an organic alternative article at: <http://www.attra.ncat.org/attra-pub/lumber.html>.

There are several arsenic-free wood pressure-treatment alternatives to CCA on the market, including:

1. **Alkaline copper quaternary (ACQ)** is a water-based preservative that leaves a dry, paintable surface. ACQ is registered for use on lumber, timber, landscape ties, fence posts, building and utility poles, land, freshwater and marine pilings, sea walls, decking, wood shingles, and other wood structures.
2. **Borates** are not recommended because they readily leach if exposed to rain or wet soil. Use the treated wood above ground and protect it from the weather. Typical applications include furnishings and interior construction, such as framing, sheathing, sill plates, furring strips, trusses, and joists.
3. **Copper azole** is a water-based preservative that leaves wood with a clean, paintable surface when dry. Copper azole is registered for treatment of millwork, shingles and shakes, siding, plywood, structural lumber, fence posts, building and utility poles, land and freshwater pilings, composites, and other wood products that are used in fresh and saltwater applications above ground and at ground level. The compound consists of amine copper with cobiocides and is used to treat a wide range of wood species.

Two other preservatives, **cyproconazole and propiconazole**, are not intended for use where wood comes in contact with the ground.

MODIFIED WOODS

Some companies are modifying wood by pressure-treating with nontoxic substances. Two examples are TimberSIL™ and Accoya wood.

1. TimberSIL™ engineered wood is made of southern yellow pine and is treated using sodium silicate and redried. It is nontoxic and lighter in weight than traditional treated wood, it weathers to a silver gray, and it is paintable or stainable. It is noncorrosive, fire retardant, noncarcinogenic, insoluble, and will not leach. It has a 40-year guarantee against rot, decay, and most wood-protection problems. It is recyclable. Visit the Web site at: <http://www.timbersilwood.com/>. Contact the company directly for further information and availability.

Figure 13—TimberSIL™ lumber.

Figure 14—TimberSIL™ picnic table.

Table 1. Table of materials and characteristics

Material Characteristics	Recycled Plastic	Composites	Composite/ Fiberglass	PVC	Decay Resistant Woods	Tropical Hardwoods	Aluminum	Rubber
Maintenance	Little	Little	Little	Little	Periodic	Little to none	None	None
Appearance	Artificial	Artificial	Artificial	Artificial	Natural	Natural	Artificial	Artificial
Colors	Various	Various	Various	Various	Natural	Natural	Various	Various
Uses recycled material	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes
Recyclable	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes
Rot/rust resistant	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Termite/mold/ fungi resistant	Yes	Yes	Yes	Yes	Only heartwood resists decay, not sapwood	Yes	Yes	Yes
Moisture resistant	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Skid/slip resistant	Yes	Yes	Yes	Yes	No	Yes	Yes	If grooved
Splinter, scratch, crack, warp resistant	Yes	No	Yes	Yes	No	Yes	Yes	Yes
UV resistant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Lifespan in years	40-50	40-50	40-50	50+	20-25	50+	20	20-30
Non-toxic	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Structural applications	No	No	Yes	No	Yes	Yes	No	No
Environmentally friendly	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table 1. Table of materials and characteristics (continued)

Material Characteristics	Recycled Plastic	Composites	Composite/ Fiberglass	PVC	Decay Resistant Woods	Tropical Hardwoods	Aluminum	Rubber
Flexible	Yes	Yes	No	Yes	Yes	No	No	Yes
FSC certified sustainably harvested	N/A	N/A	N/A	N/A	Yes	Yes	N/A	N/A
Toxin/ preservative-free	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Class A fire rating	Yes	No	No	Yes	No	Yes	Yes	Yes
Weight	Heavy	Heavy	Heavy	Medium	Heavy	Heavy	Light	Heavy
Easy installation	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Stain/mildew	Yes	Yes	No	Yes	Yes	Yes	No	No
Expansion/ contraction	Yes			Yes	Yes	Yes		No
Heat retention	Moderate	Moderate	Moderate	Low	Low	Low	Moderate	Low

2. Accoya wood is produced by Titan Wood in Arnhem, the Netherlands. According to the Web site, the technology is based on acetylation. The process completely permeates the wood and makes wood more dimensionally stable, durable, and resistant to rot, decay, and UV rays. They estimate that the wood should last about 25 years in in-ground installations and 50 years in aboveground use. It is nontoxic and can be recycled and reused safely. Visit their Web site at: <http://www.accoya.com>.

CONCLUSION

When building or replacing a trail structure, there are many materials from which to choose. Technology continues to change and improve materials that are available. Each material has its own unique advantages and disadvantages. No one material is completely maintenance free and lasts forever. Each material requires some degree of maintenance, and some materials will last longer than others but have slightly different appearances. There are many options available to fit the setting, use, cost, maintenance, and desired results.

APPENDIX A - CASE STUDIES

Case Study 1: Puncheon With Plastic Lumber on Iron Goat Trail

Location: Pacific Northwest Region (R-6), Mt. Baker-Snoqualmie National Forest, Skykomish Ranger District

Date: March 4, 2010

In 2004, Tom Davis evaluated a different option for a 200-foot-long puncheon on the Iron Goat Trail. This partnership project with Volunteers for Outdoor Washington is a front-country trail on an old railroad grade, built to Americans with Disabilities Act specifications. Previous puncheons on the trail had been built with treated wood, and there were issues with slippery wood decks due to the heavy leaf fall and wet environment. Davis also was concerned about long-term maintenance and replacement costs. In addition, the puncheon site was a wetland with skunk cabbage, and there were some concerns about utilizing treated wood in such a wetland. After researching options and looking at some docks on lakes in the city of Seattle parks, he decided to utilize 100 percent high-density polyethylene (HDPE) plastic lumber. This choice will have a longer useful life because it does not rot, seems to be more environmentally friendly, and appears to provide good traction.

Since the plastic lumber is not as strong as a similar sized piece of treated wood, the staff (we) used four stringers instead of the usual three for treated wood to provide a 5-foot-wide deck. There were also more sills than if we had used treated wood. The stringers (joists) were 100 percent HDPE with fiberglass rods to provide structural strength. The sills, deck, and curbs were 100 percent HDPE. We chose a dark brown color to blend with the surroundings. We used galvanized Simpson timber ties for the sill/stringer attachments, stainless steel deck screws to attach the deck, and galvanized bolts to attach the curbs.

The puncheon site was over a mile from the trailhead, and transporting a huge pile of lumber to the work site with a motorized wheelbarrow would have been time consuming, so we flew all the material to the work site by helicopter in about half a day.

Figure A.1—Helicopter bringing in bundles.

Volunteers built the puncheon over the summer of 2004. It took about 30 work days with 4 or so volunteers per day. The project was very labor intensive. And, since there were more pieces of lumber than a treated wood puncheon, the amount of time involved installing the sill and attaching all the pieces was increased. An onsite generator powered the drills and the holes were predrilled.

Figure A.2—Volunteer building the trail.

The plastic lumber cost $12,000, which was about twice as much as treated lumber; installation time was probably about twice as much too. However, the manufacturer said the plastic material should last 50 years or more, whereas treated wood puncheons on the same trail are having slippery deck issues after 10 years, and we may have to replace them after 20-25 years. After 5 years of use, the puncheon with plastic lumber is in good condition, and we are pleased with the results. The deck isn't slippery and we have not done any maintenance on it. At some point we will need to remove any algae.

Figure A.3—Trail is 5 years old.

Heavy snow loads a couple of winters ago caused the curbs to bend but they bounced back to normal. The puncheon is located in a shady spot, so issues with direct sunlight and warping are not a factor.

Figure A.4—The puncheon in May 2008 after a winter of very heavy snow loads. After the snow melted and some summer heat, it bounced back to normal (or so close to normal it's not noticeable).

Case Study 2: Floating Boardwalk at Crown Hill Kestral Pond

Location: Jefferson County, Golden, CO
Date: 1990s

In Golden, CO, B.J. Ellison, architect and open-space planner for Jefferson County Open Space, said they installed a floating boardwalk at Crown Hill in their Kestral Pond wetland area, a park in Wheat Ridge (figure A.5). They used Superdeck when they built the boardwalk 10 to 16 years ago and are looking to replace it. They are thinking about putting in a helical pier (a steel shaft with helices, similar to a large screw, that provides a foundation support). They are commonly used to correct and support existing foundations that have settled or failed. Ellison said the boardwalk is not really in bad condition. However, the most common complaint is that it is too bouncy or spongy when it is hot. One of the photos shows what happens if the guidepost is not high enough and allows the guide bracket to become misaligned (figures A.6, 7).

Figure A.5—Kestral Pond boardwalk.

The bracket in this case is stuck on the top of the post and is warping the deck. They used Trex™ as fillers at the transitional angles (figure A.8), and that is holding up well. In their renovation efforts, Ellison may suggest that they add Trex as a more user-friendly wearing surface, rather than replace the entire system.

Figure A.6—Kestral Pond boardwalk.

Figure A.7—Kestral Pond boardwalk.

Figure A.8—Kestral Pond boardwalk.

Case Study 3: Ipe-Wood Trail Bridges

Location: Pacific Southwest Region (R-5), San Bernardino National Forest, Fawnskin, CA
Date: 1998 or 1999

Trail bridges were installed in 1998 or 1999 and have lasted well with little or no maintenance. They are made of Ipe wood and are expensive, but due to high vandalism, they are well worth the investment because people cannot carve on them. The forest staff would definitely use this material again.

Figure A.9—San Bernardino National Forest trail bridge.

Figure A.10—Downstream view of the Ipe-wood bridge.

Figure A.11—San Bernardino National Forest trail bridge.

Case Study 4: Picnic Tables, Jenks Lake

Location: Pacific Southwest Region (R-5), San Bernardino National Forest, Jenks Lake
Date: 1996

Picnic tables were built of Ipe wood and installed in 1996. They get heavy day use. The picnic tables are in excellent shape with little or no carving, extremely heavy, and cannot be moved easily.

Figure A.12—Jenks Lake picnic table made of Ipe tropical hardwood. Notice the denseness of the Ipe wood.

Figure A.13—Jenks Lake picnic table made of Ipe tropical hardwood. Visitors cannot lift it and there is no carving on it; the wood is too dense and heavy.

Case Study 5: Silver Lake Nature Center

Location: Silver Lake Nature Center, Bristol, PA
Date: 1998

Robert Mercer, Director-Naturalist of the Silver Lake Nature Center, said: "Our first boardwalk was installed in 1998. The material is holding up well. Most of our bridges were built completely with recycled plastics (undercarriage post-consumer recycled, and the deck is preconsumer recycled). The joist or load-bearing boards were a special product with some fiberglass mixed in with the plastic for strength. I do think some of the product came without the fiberglass strengthener because we did have a few minor board failures when one year the temperature dropped to below zero.

"There are several issues with the plastic. One is the expansion of plastic along the length of the board, not like wood, which expands on the width. Therefore, the structure needs to be able to flex with temperature. Our boardwalks are serpentine, and the bends act like springs allowing for the expansion and contraction of the plastic. Our structure also allows us to just shift the structure if it is moved during a flood. Maximum amount of repair time to date was 9 man hours to repair and reposition 1,400 feet of walkway.

"Another issue is combustibility. We did have someone set on fire and burn a section of our boardwalk. The plastic is hard to ignite, but once it was burning it was hard to put out and produced a strong hot flame.

"A minor annoyance is the static electric charges. Since plastic is a poor conductor, people are not grounded and as they walk they build a static charge. Some kids get a big kick out of shocking everybody. Would I choose the material again? Yes. I do think it is important that we demonstrate what we preach, and using recycled material is important.

"The structures are still very nice looking and in 10 years have not required the slightest maintenance beyond sweeping. I have noticed a few of the boards are showing some minor spalling on the inner surface, which is the thinnest portion of the board. We have not had anyone slip on or complain about the structures (other than the shocks)."

Figure A.14—Silver Lake Nature Center boardwalk.

Figure A.15—Children on Silver Lake Nature Center boardwalk.

Case Study 6: Lakeshore Boardwalk, Lake Superior, Duluth, MN

Location: Lakewalk, Lake Superior, Duluth, MN
Date: 1988

Lake Superior's lakeshore boardwalk, called the Lakewalk, is an ongrade Ipe boardwalk about 2.5 miles long. It was built in 1988 and has worn like iron. It has weathered to a silver-gray color and is not maintained with any stain or UV protection.

During construction, builders used carbide-tipped drills and carborundum blades or a diamond saw to cut it because the wood is so hard and dense. The wood does not float.

Extreme weather ranges from -40 ºF to 105 °F. Late October northeasters cause lake surges (figures A.16, 17) that displace the boardwalk. After the storm passes, crews pick up the boardwalk and put it back into place.

Their experience includes (1) no reported slip-and-fall accidents, and (2) it does not seem too slippery. They think the ice melts off better from Ipe than it does from asphalt, but this is just an observation. Kent Worley, landscape architect, from Duluth, MN, states: "With our lakefront exposure, concerns for slipperiness when wet were unfounded because the texture "opens" enough to provide good walking traction." See http://www.ironwoods.com/thi_retailers_wholesalers.html.

Figure A.16—Duluth, MN, Lakewalk made of Ipe wood.

Figure A.17—Lake Superior. Lake surge takes out boardwalk during storm.

Case Study 7: Corkscrew Swamp Boardwalk

Location: Corkscrew Swamp, Naples, FL
Date: 1995

Corkscrew Swamp boardwalk in Florida was installed in 1995 and has 2.25 miles of Pau Lope (Ipe) boardwalk.

Figure A.18—Corkscrew Swamp trail in Naples, FL.

According to a Corkscrew Swamp Sanctuary July 2007 newsletter, "Along the Boardwalk," visitors often ask questions about the boardwalk and the wood.

Construction of the main boardwalk was begun in the fall of 1995 and completed in the late spring of 1996. The wood is Ipe (Tabebuia serratifolia). It has twice the strength and five times the hardness of pine and is extraordinarily fire resistant. Unlike pine, Ipe does not rot, decay, or succumb to termites, and it needs no chemical treatment. It is extremely attractive.

Other alternatives for the boardwalk were considered and tested. One was "play wood," composed of a mixture of recycled plastic and fiberglass; however, it was also very flammable, which would have made future prescribed burning a challenge. Pressure-treated pine was much less expensive, and although the risk of leaching arsenic into the soil and water was minimal, its short life span presented the problem of what to do with the old, arsenic-treated wood when it needed to be replaced. Tropical hardwoods have been in use for many years. Portions of the Coney Island boardwalk use Ipe and have withstood over 50 years of use and exposure with no apparent wear. The Ipe boardwalk should last at least 80-90 years, while pine might last 8-10 years and cypress 12-15 years. So while it costs 1½ times that of traditional woods, it more than pays for itself in the long run. The purchase of Ipe from a reputable supplier using sustainable forestry practices rewards and promotes sustainable forestry.

Case Study 8: Extruded Aluminum Bridge Deck, Clark County, KY

Location: Kentucky State Road 974 Bridge, Clark County, KY
Date: 2010

Traffic crossing the Kentucky State Road 974 bridge over Howard Creek in Clark County, KY, will drive over an extruded aluminum bridge deck (figure A.19). It will be the first aluminum bridge deck in Kentucky and one of a handful of load-bearing aluminum transportation structures in the country.

Figure A.19—Aluminum bridge in Kentucky.

The design features 12 deck panels fabricated from extruded profiles welded side by side. The profiles were constructed from 6005-T6 marine-grade alloy. According to Issam Harik of the Kentucky Transportation Center, the three primary advantages of the aluminum deck are:

- Reduced dead load—the aluminum deck weighs approximately 80 percent less than the steel-reinforced concrete deck it is replacing, which permits increasing the load limit for trucks crossing the bridge.
- Durability—aluminum is expected to increase the lifespan of the deck many times over that of a conventional reinforced concrete deck.
- Rapid construction—the aluminum deck can be placed in one day and the bridge opened to traffic later that same day.

Initial cost is the primary disadvantage of the aluminum deck.

APPENDIX B - REFERENCE MATERIAL

Recreation Opportunity Spectrum (ROS) Considerations

	Urban	Urban Fringe	Rural	Backcountry Drive-in	Backcountry Walk-in	Remote	Wilderness
Wood	X	X	X	X	X	X	X
Plastic	X	X	X	X	X	X	
Fiberglass	X	X	X	X	X		
Aluminum	X	X	X				
Rubber	X	X	X	X	X		

Built Environment Image Guide Considerations
See the following link for Built Environment Image Guide (BEIG) information: <http://www.fs.fed.us/recreation/programs/beig/>.

Forest Stewardship Council
The Forest Stewardship Council (FSC) is an international, not-for-profit, membership-based organization consisting of a diverse group of representatives from environmental and social groups, the timber trade and the forestry profession, indigenous people's organizations, responsible corporations, community forestry groups, and forest product certification organizations from around the world. The FSC promotes responsible stewardship of the world's forests and works to be recognized as the global center of excellence in the development of international standards for forest certification. It has a rigorous, independent assessment process, including stakeholder consultation and ongoing monitoring. Buying FSC-certified forest products supports environmentally responsible, socially beneficial, and economic viable management of the world's forests. The FSC label guarantees that the timber comes from well-managed forests according to internationally agreed upon standards. All FSC-certified wood carries the FSC logo (Forest Stewardship Council).

Tropical Forest Foundation
The Tropical Forest Foundation (TFF) was formed in 1990 as a result of a Smithsonian Institution workshop that brought together leaders of industry, science, academia, and conservation communities, and the world's major supplying and consuming regions, to address the growing concern for the protection of tropical forests. TFF was established to foster dialogue and alliances between industry groups, improve tropical forest management, and enhance the economic value of tropical forests. Upon its inception, TFF established itself as an international organization dedicated to promoting tropical forest conservation and management through education and training.

TFF's sustainable forest management brings together conservation and industry leaders in an effort to improve management by promoting the use of low-impact logging practices. Their primary focus is to demonstrate sustainable forest management through low-impact logging. Visit <http://www.tropicalforestfoundation.org> for more information.

Janka Hardness Scale

Woods are rated on the Janka Hardness Scale. The Janka rating is determined by the number of pounds of pressure required to press a stainless steel ball with a diameter of 0.444 inches halfway into the side of a board; the higher the number, the harder the wood. The hardness of wood usually varies with the direction of the grain. If testing is done on the surface of the plank, with the force exerted perpendicular to the grain, it is said to be of "side hardness." "End" testing is also sometimes done on the cut surface of a stump. There is a slight difference in the results between the "side" and "end" hardness. More commonly, "side hardness" is used. Wood is tested at 12-percent moisture content, typical of air-dried wood.

RESOURCES

Forest Products Laboratory
One Gifford Pinchot Drive
Madison, WI 53726-2398
Voice: (608) 231-9200
FAX: (608) 231-9592
TTY: (608) 231-9544
Web site: <http://www.fpl.fs.fed.us/rwu4706/index.html>.

Washington State University
Wood Materials and Engineering Laboratory (WMEL)
P.O. Box 641806
Pullman, WA 99164-1806
Mike Wolcott, Ph.D.
Phone: (509) 335-6392
Web site: <http://www.wmel.wsu.edu/>.

BIBLIOGRAPHY

American Recycled Plastic, Inc., 1500 Main Street, Palm Bay, FL 32905; (866) 674-1525; <http://www.itsrecycled.com/infoprocess.shtml>.

Buying recycled in estates management case study, recycled plastic boardwalk, Howden Marsh Local Nature Reserve, The Waste & Resources Action Programme (WRAP). June 2004.

California Department of Resources Recycling and Recovery (CalRecycle) <http://www.calrecycle.ca.gov/Plastics/recycled/Lumber/>.

Chenu, Andrea J; Loux, Jeffrey. 2006. How green is it? Composite lumber for consumer and residential applications from sustainability and the built environment. Online. Available at: <http://extension.ucdavis.edu/unit/green_building_and_sustainability/pdf/resources/how_green.pdf>.

Coastal Contractor Magazine, January/February 2006. Williston, VT: Installing Ipe Decking.

Corkscrew Swamp Sanctuary. Along the boardwalk. July 2007. In case a visitor asks. 4 p.

County Floors, 3685 Main Street, Warrensburg, NY 12885; (518) 623-9339, <http://www.countyfloors.com/species_ipe.html>.

Dynalab Corporation, 350 Commerce Drive, Rochester, NY 14623; Tel: (585) 334-2060, (800) 828-6595, Fax: (585) 334-024; Email: labinfo@dyna-labware.com; Web site <http://www.dynalabcorp.com/technical_info_pvc.asp>.

Forest Products Laboratory. 1999. Wood handbook—Wood as an engineering material. Gen.Tech.Rep. FPL–GTR–113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 463 p.

Forest Products Society, 2801 Marshall Court, Madison, WI 53705-2295. phone: (608) 231-136; fax: (608) 231-2152; <http://www.forestprod.org/>.

Forest Stewardship Council, 11100 Wildlife Center Drive, Suite 100, Reston, VA 20190, 703.438.6401, www.fscus.org. [Online]. Available: <http://www.fsc.org> and <http://www.fscus.org/faqs/fsc_products.php?link=2>.

Frechette, Leon A. 1999. Build smarter with alternative materials. Carlsbad, CA: Craftsman Book Company. 333 p.

Groenier, James Scott; Eriksson, Merv; Kosmalski, Sharon. 2006. A guide to fiber-reinforced polymer bridges. 0623–2824–MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 98 p.

Groenier, James Scott; LeBow, Stan. 2006. Preservative-treated wood and alternative products in the Forest Service. 0677–2809–MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 44 p.

Joint Service Pollution Prevention and Sustainability Technical Library. A Web Site Supported by the Joint Services, the Defense Logistics Agency, and the U.S. Coast Guard, P2 Opportunity Handbook Data Sheets <http://205.153.241.230/P2_Opportunity_Handbook/7_I_A_11.html>.

Mitsubishi Chemical. 2006. Three main properties of carbon black. [online] May 4, 2010. <http://www.carbonblack.jp/en/cb/tokusei.html>.

Plastic Lumber Yard® 220 E. Washington Street, Norristown, PA 19401, (610) 277-3900; <http://plasticlumberyard.com/>.

Rumber Materials, Inc., 621 West Division Street, Muenster, TX 76252; 1-877-RUMBER1, (940) 759-4181; <http://www.rumber.com>. [n.d.], [Online]. Available: <http://www.rumber.com>.

Steinholz, Robert T.; Vachowski, Brian. 2007. Wetland trail design and construction: 2007 edition. 0723–2804–MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 90 p.

Thornton, Joe. [online] Environmental impacts of polyvinyl chloride (PVC) building materials. A briefing paper for the Healthy Building Network. Healthy Building Network, 927 15th Street, NW, 4th Floor, Washington, DC 20005. Phone: (202) 898-1610; fax: (202) 898-1612, <http://www.healthybuilding.net>.

Winterbottom, Daniel M. 2000. Wood in the landscape. New York: John Wiley & Sons, Inc. 204 p.

The National Technology and Development Center's national publications are available on the Internet at: <http://www.fs.fed.us/eng/pubs/>.

Forest Service and U.S. Department of the Interior, Bureau of Land Management employees also can view videos, CDs, and National Technology and Development Center's individual project pages on their internal computer network at: <http://fsweb.sdtdc.wo.fs.fed.us/>

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