AN OVERVIEW OF NONPOINT SOURCE POLLUTION IN THE SOUTHERN UNITED STATES

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Abstract.—This paper examines nonpoint source pollution (NPSP) in the thirteen states of the Southern Region. The definitions, sources, types, and trends of NPSP are discussed. NPSP is of particular concern to wetlands because it is difficult to manage and most states have little knowledge of the effects on wetlands. Information is very limited on the cumulative effects of different NPSP sources on wetlands. Where water quality is deteriorating, NPSP is frequently the major cause. Best management practices implemented by local and state agencies provide the best means of controlling NPSP.

INTRODUCTION

During the past 15 years the definitions, attitudes towards, and philosophical approaches to nonpoint source pollution (NPSP) have changed substantially. The original focus of water pollution research and control in the late 1960's and early 1970's was on point sources because they were the major cause of deterioration in the quality of surface waters in the United States. At that time, NPSP was considered to be a small part of the water pollution problem. Research was started on the sources, effects, and control of NPSP in response to passage of the Water Pollution Control Act Amendments of 1972, Public Law 92-500. By the time the Clean Water Act was enacted in 1978, hundreds of projects on NPSP were in progress (Chesters and Schierow 1985).

Research quickly determined that the magnitude of NPSP was much larger than originally believed and that over half of all the water pollution was nonpoint in nature. The magnitude of NPSP was originally underestimated because some of it is due to natural causes, it is often difficult to separate from point source pollution, and baseline information was lacking. Ultimately, NPSP was found to play a major role in the remaining water quality problems in this country. Where water quality showed deteriorating trends, NPSP was identified as the main source (Smith et al. 1987; EPA 1984).

Water quality researchers and managers have difficulty in coming to grips with NPSP. Unlike point source NPSP is a landscape-scale phenomenon and thus the land area involved is enormous. Some NPSP (i.e., sediment) is due to natural conditions as identified by some long-term NPSP records. But some of these NPSP problems may be aggravated by control of NPSP elsewhere on the landscape (i.e., stream bed and bank sediment transport subsequent to reductions in upstream erosion). There is also a considerable problem with establishing cause and effect relationships between NPSP and water quality problems. In-stream NPSP, released years ago and stored in sediments, wetlands, and water bodies, may provide continuous water quality problems long after the NPSP source has been controlled.

NPSP has proved to be a management problem since it frequently is intractable to economical, legal, and institutional management efforts. Site-specific prescriptions to control NPSP are often made difficult by political relations between governmental bodies, and, frequently, workable prescriptions will not work everywhere.

NPSP is a major environmental concern in the South because of the region's abundant water resources (Table 1; EPA 1984). Surface waters have been the prime focus of NPSP research and management because they provide much of the region's domestic water supply and recreational opportunities. In some states, wetlands are more abundant than perennial surface waters. As development has encroached upon these wetlands, and our understanding of the importance of wetlands in regulating surface hydrology and providing wildlife habitat has Improved, the need to better understand the impacts of NPSP on wetlands has become very urgent.

Table 1.—Wetlands, rivers, and lake resources by state, Southern Region

	Wetlands		Surface water	
State	Inland	Tidal	Rivers	Lakes #
	ha	ha	km	ha
AL	1,052,168	161,872	65,338	281,469
AR	364,212	0	18,027	249,112
FL	4,300,094	604,960	18,861	929,943
GA	1,941,655	202,340	32,186	277,069
KY	59,638	0	64,372	284,087
LA	1,214,093	1,043,518	479,224	502,589
MS	259,805	*	16,534	307,351
NC	1,507,028	1,492,055	59,866	229,777
OK	21,448	0	37,014	542,822
SC	1,681,850	203,959	15,576	356,173
TN	318,483	0	30,956	423,760
TX	121,404	64,749	128,744	1,198,029
VA	U	86,197	43,837	86,162

Includes lakes, ponds, and reservoirs; * = data included in figures reported for estuaries.

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Forested wetlands entered into the NPSP picture from two different directions. Traditionally, wetlands were considered to be a filter for mitigating point source and NPSP fluxes into aquatic ecosystems (Todd et al. 1983; Lowrance et al. 1985). Forested wetlands often occur between upland sources of NPSP and the aquatic systems prized for their wildlife, recreational, and aesthetic values. But then, it was recognized that NPSP has a major impact on the intrinsic values of wetland ecosystems. For forested wetlands in particular, forestry practices represent a major source of NPSP. The real difficulty in dealing with NPSP in relation to wetlands lies in defining NPSP and determining its impacts.

DEFINITIONS AND TERMINOLOGY

Terminology

To define NPSP, such basic terminology as "water quality," "water contamination," and "water pollution" must be defined. Often these terms are not clearly defined and are confused with each other.

Water **quality.—This** is a neutral term relating to the condition or composition of water as affected by natural processes and cultural activities. It is classified as "good," "fair," "poor," etc., relative to its intended use. For example, most people have an intuitive sense of what constitutes good water quality, but there can be disagreement over this term. Water quality and water pollution are determined by comparison to sets of standards, objectives, criteria, etc. While some water quality standards are universally accepted, others are not.

Water **pollution.—This** term relates to some objective, usually undesirable change in the condition of water relative to standards and criteria. Often, subjective criteria are interjected into the determination of water pollution. This occurs because of misunderstandings of what constitutes the "natural" condition of water resources.

Water **contamination.—This** term refers to the presence of non-water materials in water such as elements, minerals, organic and inorganic chemicals, biological debris, and living organisms. All water is contaminated to some extent, but not all water is polluted.

NPSP Definition

According to the classical definition, there are three characteristics which distinguish NPSP from point sources of pollution (Vignon 1985). The first characteristic of NPSP is that of a dominant overland and/or subsurface flow component which must occur to transport pollutants. These modes of transport are not amenable to analysis by traditional open-channel hydraulic techniques and, thus, are difficult to relate to processes generating sources of pollutants (in contrast to the end of a pipe discharging wastes into a stream). A second characteristic of NPSP is that it is intermittent in both time and space. The variability associated with intermittent behavior makes NPSP difficult to quantify and manage. The third basic attribute of NPSP is that the pollution originates in a diffuse manner from a large and broad landscape. Thus, it is difficult to couple causal relationships the substantial volumes of water aad associated pollutants that are generated across entire watersheds.

Vignon (1985) suggested expanding the distinguishing characteristics of NPSP to include factors other than physical-chemical considerations. The jurisdictionally descriptive complexity of NPSP is more uncertain than for point source pollution because few NPSP problems are the responsibility of a single jurisdictional entity. Furthermore, NPSP involves a broader array of agencies and individuals than is concerned with point source pollutant generation and water quality management. Finally, NPSP is distinguished from point source pollution in that it is resistant to regulatory-based control.

NPSP SOURCES

There are six main source activities of NPSP. The first five are the traditional sources: agriculture, silviculture, mining, construction, and urban activities. The sixth, atmospheric deposition, has only been recognized in recent years, but is a major contributor of some types of NPSP in certain regions. Agriculture is by far the most pervasive NPSP in the thirteen-state Southern Region (Table 2). Silviculture is primarily a localized problem but can affect high quality waters used for human consumption and fisheries habitat. Urban and construction sources are also localized problems, but in some states they affect a major portion of the water resources. Mining occurs in localized areas, but can produce some severe NPSP problems.

Table 2.—NPSP problems by state and source (EPA 1984; Myers et al. 1985)

State	Agr	Sil	Min	Con	Urb
AL	XXX[1]	**[2]	**	**	**
AR	XXX	**	**	—[3]	**
FL	XXX	**	**	**	XXX
GA	XXX	**	**	**	**
KY	XXX	**	**	**	**
LA	XXX	**	**	**	**
MS	**	**	**	**	**
NC	XXX	XXX	**	**	**
OK	**	**	**	**	**
SC	XXX	**	**	**	**
TN	XXX	**	**	**	**
TX	0[4]	0	0	0	0
VA	XXX	**	**	XXX	XXX

[1] XXX = Major NPSP problem affecting >50% of a state's waters.
[2] ** = Localized NPSP problem.
[3] -- = Minor problem or does not occur in the state.
[4] 0 = Not reported.

Agriculture

Since agriculture constitutes the most extensive and intensive land use activity it is not surprising that it accounts for much of the NPSP in the Southern Region. Activities such as field tillage, pesticide and fertilizer applications, drainage, irrigation, grazing, and feed-lot operations contribute to NPSP. In addition, agricultural operations occur annually (or monthly during the growing season) on the same landscape.

Silviculture

Forestry operations may be as intensive as agriculture, but occur far less frequently and are less extensive in nature. The types of activities which affect NPSP include road construction, vegetation removal, fertilizer and pesticide applications, burning, and mechanical equipment operations. The hydrologic functions of forested watersheds are much different than agricultural ones, thus the magnitudes and routing of NPSP are often different.

Mining

Surface and underground mines can produce large quantities of NPSP. Activities which contribute to NPSP include access road construction, vegetation clearing, overburden removal, rock extraction, and backfilling operations. Ore processing waters and acidic mine and tailing leachates also contribute to NPSP.

Construction

Construction of physical facilities including homes, businesses, manufacturing plants, roads, and utility corridors result in land disturbances which generate NPSP. While this source of NPSP is usually localized, states such as Florida that are undergoing major population expansions can have significant problems with construction-generated NPSP. The major population growths in this and other major wetland states are expected to occur within 80 km of the coast where most wetlands are located.

Urban

Storm water drainages from urban areas can be a major source of NPSP for wetland areas. This is particularly true in states with large, expanding urban areas. Runoff during storm events can rapidly transport heavy metals, sewage, fertilizers, pesticides, sediment, petroleum products etc., and other manufacturing products into wetlands.

Atmospheric

This source of NPSP is still undergoing extensive research and evaluation. Atmospheric inputs are a form of natural NPSP utilized by plants (Swank 1984). Emissions from power plants, industrial facilities, vehicles, and domestic heating are certainly the most important sources of the major pollutants (sulfur and nitrogen oxides).

NPSP TYPES

The types of NPSP consist of erosional products (sediments), biologically active elements or ions (heavy metals and nutrients), synthetic organic chemicals (pesticides), and biological material. All of these materials interact with or affect the functioning of aquatic ecosystems, or affect the quality of natural waters. These NPSP types can be generated by some or all of the NPSP source activities. The NPSP types either occur naturally in terrestrial and aquatic ecosystems or are introduced. The classification of these types as pollutants is due to the quantity of flux into wetlands and aquatic ecosystems as well as adverse changes in the functioning of each system.

Sediment.—The largest contributor to NPSP by volume and the single most important water quality problem in the United States is sediment. It consists of sand, silt, clay particles, and organic matter dislodged from exposed soil, stream channel banks, and channel beds. The enormity of sediment contributions is reflected in the topsoil loss from agriculture in the thirteen-state Southern Region. Some 16.1 million hectares of cropland is 8 metric tons/ha/yr, with substantial portions being deposited in waterways or adjacent wetlands (Larsen et al. 1983). The cost of this sediment loading is estimated to be $6 billion per year nationally (Clark 1985).

As a NPSP source, sediment is complex since many other pollutants are transported with sediment. These sediment-bound pollutants (i.e., nitrogen, phosphorus, potassium, pesticides, heavy metals. etc.) are less available biologically can be buried with deposited sediment. However, sediment-bound pollutants that do not degrade can be reintroduced into aquatic systems, and can hasten the eutrophication of slow-flushing bodies of water such as lakes, ponds, and wetlands.

Heavy metals.—A variety of these metals may occur in toxic concentrations, they do not degrade, and can bioaccumulate in aquatic ecosystems. Heavy metals originate from sources such as sewage sludge, urban runoff from industrial areas, transportation activities, building materials, mining leachates, and tailing sediments. Most heavy metals are either sediment-adsorbed or complexed and are transported with these materials.

Anions/cations or nutrients.—Anions and cations that serve as plant and animal nutrients are generated naturally across landscapes. However, human activities usually magnify the levels at which nutrients are introduced into natural waters and wetlands. Land use activities such as fertilizer application, animal grazing, vegetation removal, land clearing, and storm runoff channeling are major sources of nutrients. Nationally, cropland, rangeland, and pastures contribute almost 7 million metric tons of nitrogen and 3 million metric tons of phosphorus to surface waters. In the thirteen states of the Southern Region, eroded sediments alone carry 1.2 million metric tons of nitrogen (Larsen et al. 1983). Additional nitrogen is transported in solution. Loehr (1974) compared the different concentrations and areal loadings of nitrogen and phosphorus produced by various land uses (Figures 1 and 2). Intensive agricultural practices clearly produce both higher concentrations and loadings of N and P compared with other sources. It is also important to note that precipitation ranks high in N loading.

Biological.—Biological NPSP consists mainly of fecal organisms associated with feedlots and sewage. This type of NPSP is usually rather localized, but shock loadings and localized problems from livestock farming areas and urban runoff can occur.

Pesticides and organic **chemicals.**—NPSP of this type originates from use of Herbicide, and insecticide NPSP originates in agriculture, in forestry, lawn care practices, and from the manufacture, transportation, and use of synthetic organic chemicals. Storm runoff and urban storm water are the main mechanisms for moving these materials into surface waters and wetlands.

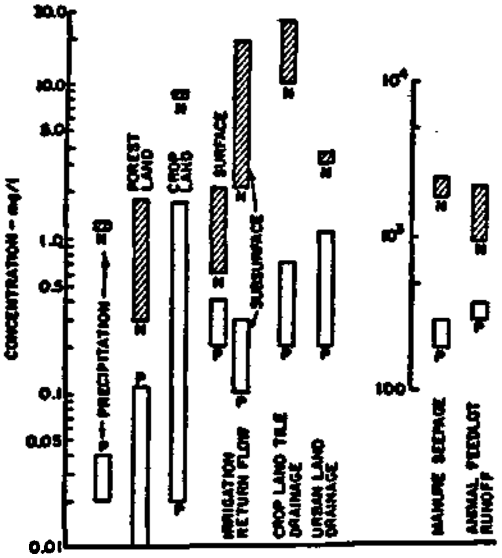

Figure 1.—Comparison of nonpoint sources, giving range of total N and P concentrations (Loehr 1974).

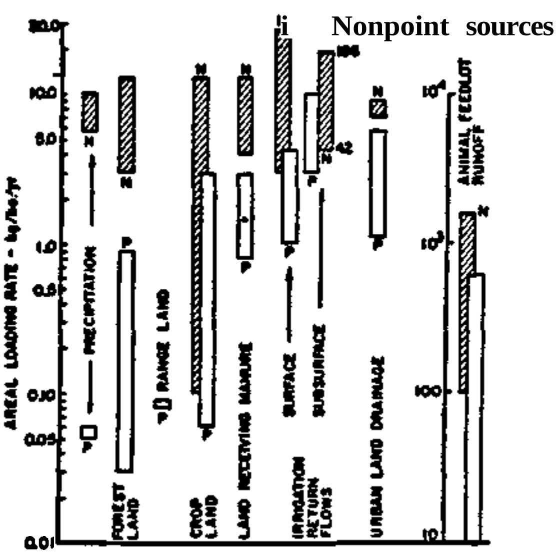

Figure 2.—Contributions of total N and P by various nonpoint sources (Loehr 1974).

Pesticide use alone amounts to about 1.2 million metric tons per year, with 75% of that being in agriculture (EPA 1984). While concentrations of pesticides are relatively low in surface waters, chronic toxicity problems with aquatic and wetlands biota can occur in certain situations (Wauchope 1978).

CUMULATIVE AND OFF-SITE EFFECTS

The off-site water quality effects of NPSP have been well documented for surface waters (Tables 3a and 3b). Many of the same qualitative effects can be found in wetlands. However, few of these effects have been quantified for wetlands, particularly for NPSP originating from forested lands. For most forested wetlands, baseline information on NPSP effects is lacking and natural inputs of NPSP are not well documented.

Cumulative effects of NPSP are not well documented or understood. Much of the NPSP research in the past has concentrated on outputs from specific practices on small portions of large watersheds. For wetlands, rigorous analyses of cumulative effects are needed to understand the inputs and impacts of NPSP.

NPSP TRENDS

There is considerable variation across the thirteen states of the Southern Region in the extent of NPSP assessment for rivers and lakes (Table 4; adapted from EPA 1984). Because of differences in rating NPSP or awareness of NPSP, it is difficult to make straight comparisons of NPSP impacts reported by individual states. However, some trends can be delineated. Rivers and lakes have had the first priority in terms of NPSP assessment (EPA 1984). Only five states have assessed more than 50% of their rivers, while just about half have assessed more than 50% of their lakes for NPSP effects. Of the known NPSP impacted waters, most states reported NPSP for rivers and lakes at moderate to threatened levels. In most states, agriculture is responsible for the predominant NPSP impacts. Except for two states (Arkansas and Louisiana), silviculture was responsible for < 8% of the impacts on surface waters. Urban and construction sources account for high levels of NPSP in Georgia, South Carolina, and Texas. In Kentucky, mining is an important NPSP generator. Two states, North Carolina and Oklahoma, either did not report NPSP data or were uncertain about the amount of NPSP impacts. Virginia and Texas were also uncertain of the scope of NPSP, but did report data on some of their surface waters.

In regards to wetlands, most states do not know the magnitude and sources of NPSP effects on wetlands (Table 5; adapted from EPA 1984). Kentucky, North Carolina, South Carolina, and Oklahoma reported data on percent of wetlands currently impaired by NPSP or potentially threatened. However, the data from these three states indicate that there is still great uncertainty about NPSP impacts on wetlands. Thus, much work remains to be accomplished in terms of both determining NPSP impacts and assessing the extent of NPSP to wetlands in the region.

Table 3a.—NPSP effects on aquatic systems and wetlands

Type	Source	Effects (* = pertains to wetlands)
Sediment	A,S,M[1] U,C	* 1. Decrease in light transmission through water
		* 2. Direct effects on respiration and digestion of aquatic spp.
		* 3. Decrease in viability of aquatic life
		* 4. Increased temperature of surface water
		* 5. Decreased recreational and commercial value
		6. Increase in drinking water costs
Salts	A,M,U	* 1. Favors salt-tolerant aquatic spp., and affects the types and populations of fish and aquatic wildlife
		2. Reduce crop yields
		* 3. Destruction of fish habitat and food sources
		* 4. Reduced suitability for recreation
		5. Drinking water quality affected
Pesticides	A,S,U C	* 1. Hinders photosynthesis in aquatic plants
		* 2. Lowers organism resistance and increases susceptibility to other environmental stress
		* 3. Affects reproduction, respiration, growth, and development of aquatic spp., and reduces food supply and habitat
		* 4. Lethal effects on nontarget spp.
		* 5. Bioaccumulation in tissue of fish and other aquatic spp.
		* 6. Carcinogenic, teratogenic, and mutagenic effects
		* 7. Reduces fishing and other recreational values
		* 8. Health hazard from consumption of contaminated fish and water

[1] #A = agriculture; S = silviculture; U = urban, M = mining; C = construction sources of NPSP.

Table 3b.—NPSP effects on aquatic systems and wetlands

Type	Source	Effects (* = wetlands)
Nutrients	A,S,U[1] C	* 1. Promote premature eutrophication of lakes, and estuaries
		* 2. Algal blooms
		* 3. Favor less desirable fish spp.
		* 4. Interfere with boating and fishing
		5. Reduce the quality of water supplies
		* 6. Reduce 02 levels in water
		7. Reduction of waterfront property values
		8. Health problems
Metals	U,M	* 1. Affect bottom-feeding aquatic organisms and predators
		* 2. Bioaccumulate in animal tissue
		* 3. Affect reproduction and lifespan of aquatic spp.
		* 4. Disrupt food chain in aquatic environments
		* 5. Affect recreational and commercial fishing
		6. Affect water supplies
Biological	A,U	* 1. Introduce pathogens into waters
		* 2. Reduced recreational usage
		3. Increased treatment cost of drinking water
		4. Human health hazard
Anions	M	* 1. Significant change in stream acidity
		* 2. Leaching of toxic metals
		* 3. Elimination of aquatic communities
		4. Severely limited domestic and industrial use of water

[1] A = agriculture; S = silviculture; U = urban, M = mining; C = construction sources of NPSP.

Table 4.—NPSP assessment by state, intensity, and source for rivers and lakes in the thirteen-state Southern Region; EPA 1984

State	Type	Waters assessed	Proportion of known NPSP-impacted waters								
			Intensity #			Source @					
			Sev	Mod	Thr	A	S	C	U	M	O
			%								
AL	R	30	9	73	18	71	1	1	1	42	2
	L	0	U	U	U	U	U	U	U	U	U
AR	R	100	17	13	70	51	34	8	U	7	U
	L	3	U	U	100	63	37	U	U	U	U
FL	R	40	10	45	45	60	<1	2	2	14	25
	L	44	4	6	90	93	0	<1	3	1	11
GA	R	85	27	5	68	10	4	72	26	0	0
	L	57	91	9	0	99	4	0	92	0	0
KY	R	25	-16	84	0	53	U	U	0	47	U
	L	51	0	100	0	0	0	0	0	100	0
LA	R	1	4	75	21	86	4	7	13	19	6
	L	37	1	8	91	43	47	7	8	11	16
MS	R	100	0	45	55	100	0	0	0	0	0
	L	65	0	100	0	100	0	0	0	0	0
NC	R	100	7	36	57	+	+	+	+	+	+
	L	56	0	0	100	+	+	+	+	+	+
OK	R	52	0	0	100	U	U	U	U	U	U
	L	41	0	0	100	U	U	U	U	U	U
SC	R	29	2	42	56	100	0	36	90	0	31
	L	51	0	8	92	74	0	0	12	0	<1
TN	R	31	16	49	35	61	8	1	3	29	0
	L	51	14	42	44	98	<1	<1	<1	1	0
TX	R	18	0	0	100	0	0	100	100	0	0
	L	45	+	+	+	+	+	+	+	+	+
VA	R	7	U	U	U	U	U	U	U	U	U
	L	53	0	2	98	56	6	36	2	U	U

U = Unknown; + = not reported; # = Intensity columns sum to 100%; @ = Source columns not additive.

Table 5.—NPSP assessment for inland (I) and tidal (T) wetlands in the thirteen-state Southern Region; EPA 1984

State	Wetlands		Current use		NPSP impaired		
					No current use		NPSP-PSP
	Type	Total	Sev	Mod	Threat	Minor	Mixed
		ha x 10^3	%				
AL	I	1,052	U	U	U	U	U
	T	162	U	U	U	U	U
AR	I	364	U	U	U	U	U
	T	0	-	-	-	-	-
FL	I	4,300	U	U	U	U	U
	T	605	U	U	U	U	U
GA	I	1,942	U	U	U	U	U
	T	202	U	U	U	U	U
KY	I	59	9	3	0	1	<1
	T	0	-	-	-	-	-
LA	I	1,214	U	U	U	U	U
	T	1,044	U	U	U	U	U
MS	I	260	U	U	U	U	U
	T	*	-	-	-	-	-
NC	I	1,507	0	0	26	0	0
	T	1.492	0	0	U	U	0
OK	I	21	0	0	0	0	0
	T	0	-	-	-	-	-
SC	I	1.682	0	0	0	100	0
	T	204	0	0	0	100	0
TN	I	318	U	U	U	U	U
	T	0	-	-	-	-	-
TX	I	121	U	U	U	U	U
	T	65	U	U	U	U	U
VA	1	U	U	U	U	U	U
	T	86	0	0	8	U	U

U = Unknown: * = included with estuaries; - = does not apply.

CONTROL OF NPSP

The basic elements for effective control of NPSP in surface waters as well as wetlands consist of the following:

1. Rank high-priority water bodies;
2. Identify those water quality problems in high-priority waters that are caused by NPSP;
3. Identify key NPSP sources and activities;
4. Choose appropriate best management practices (BMP's).

The key to reducing NPSP impacts is effective state management of water quality and implementation of BMP's. Decisions must be made at the local level on site-specific, high-priority problems.

While many states have implemented BMP's to control NPSP inputs into rivers and lakes from sources like agriculture and silviculture, few have developed BMP's specifically for wetlands (Florida Division of Forestry 1988; South Carolina Forestry Association Environmental Committee 1987). For most areas of the South, the information on the magnitude of NPSP inputs into forested wetlands, the effects within wetlands, and the effectiveness of BMP's is highly variable. The following paper by Riekerk, Neary, and Swank (this volume) will specifically examine these topics, and will address specific NPSP types and research needs. But, in general, there is a large need for specific process-oriented research on NPSP impact and on wetland ecosystem functions. This is one reason why, as has been illustrated, states are having difficulty with assessing the effects of NPSP on wetlands.

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