# SMART CONTRACT AUDIT REPORT

for

# Alpaca's addCollateral() Routine

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## Document Properties

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# Contents

# 1 Introduction

Given the opportunity to review the design document and related source code of the the Alpaca Finance Protocol with the inclusion of new configuration contracts, we outline in the report our systematic approach to evaluate potential security issues in the smart contract implementation, expose possible semantic inconsistencies between smart contract code and design document, and provide additional suggestions or recommendations for improvement. Our results show that the given version of smart contracts is well engineered without security-related issues. due to the presence of several issues related to either security or performance. This document outlines our audit results.

## 1.1 About Alpaca

The Alpaca Finance Protocol is a leveraged yield farming and leveraged liquidity providing protocol running on Binance Smart Chain (BSC). The audited implementation extends the previous version by adding the support of new configuration contracts, including ConfigurableInterestVaultConfig, WorkerConfig, and SingleAssetWorkerConfig. It also updates the main Vault contract for collateral addition to make the system distinctive and valuable when compared with current yield farming offerings. The basic information of the audited protocol is as follows:

Table 1.1: Basic Information of the audited protocol

| Item | Description |
|---|---|
| Name | Alpaca Finance Protocol |
| Website | https://www.alpacafinance.org/ |
| Type | Ethereum Smart Contract |
| Platform | Solidity |
| Audit Method | Whitebox |
| Latest Audit Report | August 18, 2021 |

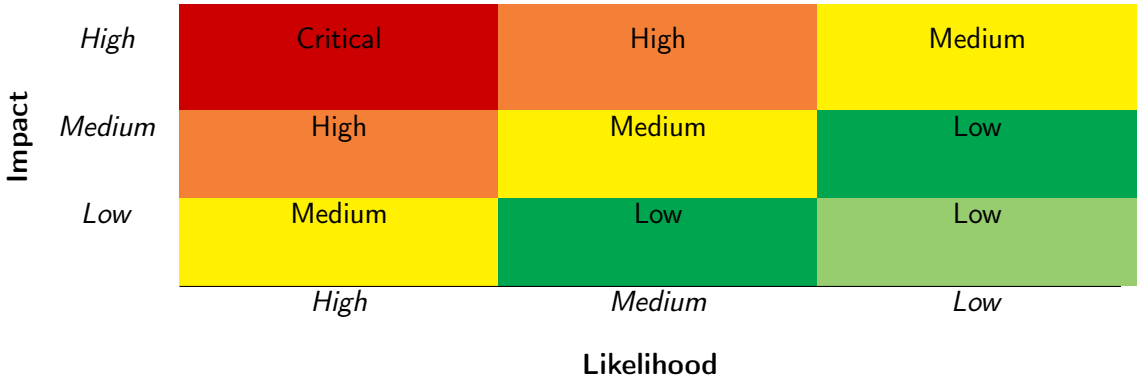
In the following, we show the Git repository of reviewed files and the commit hash value used in this audit:

- https://github.com/alpaca-finance/bsc-alpaca-contract.git (8d89033)

## 1.2 About PeckShield

PeckShield Inc. [7] is a leading blockchain security company with the goal of elevating the security, privacy, and usability of current blockchain ecosystems by offering top-notch, industry-leading services and products (including the service of smart contract auditing). We are reachable at Telegram (https://t.me/peckshield), Twitter (http://twitter.com/peckshield), or Email (contact@peckshield.com).

Table 1.2: Vulnerability Severity Classification




## 1.3 Methodology

To standardize the evaluation, we define the following terminology based on OWASP Risk Rating Methodology [6]:

- Likelihood represents how likely a particular vulnerability is to be uncovered and exploited in the wild;
- Impact measures the technical loss and business damage of a successful attack;
- Severity demonstrates the overall criticality of the risk.

Likelihood and impact are categorized into three ratings: *H*, *M* and *L*, i.e., *high*, *medium* and *low* respectively. Severity is determined by likelihood and impact and can be classified into four categories accordingly, i.e., *Critical*, *High*, *Medium*, *Low* shown in Table 1.2.

To evaluate the risk, we go through a list of check items and each would be labeled with a severity category. For one check item, if our tool or analysis does not identify any issue, the contract is considered safe regarding the check item. For any discovered issue, we might further

Table 1.3: The Full List of Check Items

| Category | Check Item |
|---|---|
| **Basic Coding Bugs** | Constructor Mismatch |
| | Ownership Takeover |
| | Redundant Fallback Function |
| | Overflows & Underflows |
| | Reentrancy |
| | Money-Giving Bug |
| | Blackhole |
| | Unauthorized Self-Destruct |
| | Revert DoS |
| | Unchecked External Call |
| | Gasless Send |
| | Send Instead Of Transfer |
| | Costly Loop |
| | (Unsafe) Use Of Untrusted Libraries |
| | (Unsafe) Use Of Predictable Variables |
| | Transaction Ordering Dependence |
| | Deprecated Uses |
| **Semantic Consistency Checks** | Semantic Consistency Checks |
| **Advanced DeFi Scrutiny** | Business Logics Review |
| | Functionality Checks |
| | Authentication Management |
| | Access Control & Authorization |
| | Oracle Security |
| | Digital Asset Escrow |
| | Kill-Switch Mechanism |
| | Operation Trails & Event Generation |
| | ERC20 Idiosyncrasies Handling |
| | Frontend-Contract Integration |
| | Deployment Consistency |
| | Holistic Risk Management |
| **Additional Recommendations** | Avoiding Use of Variadic Byte Array |
| | Using Fixed Compiler Version |
| | Making Visibility Level Explicit |
| | Making Type Inference Explicit |
| | Adhering To Function Declaration Strictly |
| | Following Other Best Practices |

deploy contracts on our private testnet and run tests to confirm the findings. If necessary, we would additionally build a PoC to demonstrate the possibility of exploitation. The concrete list of check items is shown in Table 1.3.

In particular, we perform the audit according to the following procedure:

- Basic Coding Bugs: We first statically analyze given smart contracts with our proprietary static code analyzer for known coding bugs, and then manually verify (reject or confirm) all the issues found by our tool.
- Semantic Consistency Checks: We then manually check the logic of implemented smart contracts and compare with the description in the white paper.
- Advanced DeFi Scrutiny: We further review business logics, examine system operations, and place DeFi-related aspects under scrutiny to uncover possible pitfalls and/or bugs.
- Additional Recommendations: We also provide additional suggestions regarding the coding and development of smart contracts from the perspective of proven programming practices.

To better describe each issue we identified, we categorize the findings with Common Weakness Enumeration (CWE-699) [5], which is a community-developed list of software weakness types to better delineate and organize weaknesses around concepts frequently encountered in software development. Though some categories used in CWE-699 may not be relevant in smart contracts, we use the CWE categories in Table 1.4 to classify our findings.

## 1.4 Disclaimer

Note that this security audit is not designed to replace functional tests required before any software release, and does not give any warranties on finding all possible security issues of the given smart contract(s) or blockchain software, i.e., the evaluation result does not guarantee the nonexistence of any further findings of security issues. As one audit-based assessment cannot be considered comprehensive, we always recommend proceeding with several independent audits and a public bug bounty program to ensure the security of smart contract(s). Last but not least, this security audit should not be used as investment advice.

Table 1.4: Common Weakness Enumeration (CWE) Classifications Used in This Audit

| Category | Summary |
|---|---|
| **Configuration** | Weaknesses in this category are typically introduced during the configuration of the software. |
| **Data Processing Issues** | Weaknesses in this category are typically found in functionality that processes data. |
| **Numeric Errors** | Weaknesses in this category are related to improper calculation or conversion of numbers. |
| **Security Features** | Weaknesses in this category are concerned with topics like authentication, access control, confidentiality, cryptography, and privilege management. (Software security is not security software.) |
| **Time and State** | Weaknesses in this category are related to the improper management of time and state in an environment that supports simultaneous or near-simultaneous computation by multiple systems, processes, or threads. |
| **Error Conditions, Return Values, Status Codes** | Weaknesses in this category include weaknesses that occur if a function does not generate the correct return/status code, or if the application does not handle all possible return/status codes that could be generated by a function. |
| **Resource Management** | Weaknesses in this category are related to improper management of system resources. |
| **Behavioral Issues** | Weaknesses in this category are related to unexpected behaviors from code that an application uses. |
| **Business Logics** | Weaknesses in this category identify some of the underlying problems that commonly allow attackers to manipulate the business logic of an application. Errors in business logic can be devastating to an entire application. |
| **Initialization and Cleanup** | Weaknesses in this category occur in behaviors that are used for initialization and breakdown. |
| **Arguments and Parameters** | Weaknesses in this category are related to improper use of arguments or parameters within function calls. |
| **Expression Issues** | Weaknesses in this category are related to incorrectly written expressions within code. |
| **Coding Practices** | Weaknesses in this category are related to coding practices that are deemed unsafe and increase the chances that an exploitable vulnerability will be present in the application. They may not directly introduce a vulnerability, but indicate the product has not been carefully developed or maintained. |

# 2 | Findings

## 2.1 Summary

Here is a summary of our findings after analyzing the implementation of the `Alpaca Finance Protocol` regarding the support of new `configuration` contracts and an updated `Vault`, During the first phase of our audit, we study the smart contract source code and run our in-house static code analyzer through the codebase. The purpose here is to statically identify known coding bugs, and then manually verify (reject or confirm) issues reported by our tool. We further manually review business logics, examine system operations, and place DeFi-related aspects under scrutiny to uncover possible pitfalls and/or bugs.

| Severity | # of Findings | |
|---|---|---|
| Critical | 0 | |
| High | 0 | |
| Medium | 0 | |
| Low | 1 | ■ |
| Informational | 1 | ■ |
| Total | 2 | |

We have so far identified a list of potential issues: some of them involve subtle corner cases that might not be previously thought of, while others refer to unusual interactions among multiple contracts. For each uncovered issue, we have therefore developed test cases for reasoning, reproduction, and/or verification. After further analysis and internal discussion, we determined a few issues of varying severities that need to be brought up and paid more attention to, which are categorized in the above table. More information can be found in the next subsection, and the detailed discussions of each of them are in Section 3.

## 2.2 Key Findings

Overall, these smart contracts are well-designed and engineered, though the implementation can be improved by resolving the identified issues (shown in Table 2.1), including 1 low-severity vulnerability, and 1 informational recommendation.

Table 2.1: Key Audit Findings of Vault/Configuration Contracts Protocol

| ID | Severity | Title | Category | Status |
|---|---|---|---|---|
| PVE-001 | Informational | Accommodation of approve() Idiosyncrasies | Coding Practices | Resolved |
| PVE-002 | Low | Improved Precision By Multiplication And Division Reordering | Coding Practices | Resolved |

Besides recommending specific countermeasures to mitigate these issues, we also emphasize that it is always important to develop necessary risk-control mechanisms and make contingency plans, which may need to be exercised before the mainnet deployment. The risk-control mechanisms need to kick in at the very moment when the contracts are being deployed in mainnet. Please refer to Section 3 for details.

# 3 | Detailed Results

## 3.1 Accommodation of approve() Idiosyncrasies

- ID: PVE-001
- Severity: Informational
- Likelihood: N/A
- Impact: N/A
- Target: `Vault`
- Category: Coding Practices [3]
- CWE subcategory: CWE-1126 [1]

### Description

Though there is a standardized ERC-20 specification, many token contracts may not strictly follow the specification or have additional functionalities beyond the specification. In this section, we examine the `approve()` routine and analyze possible idiosyncrasies from current widely-used token contracts.

In particular, we use the popular stablecoin, i.e., `USDT`, as our example. We show the related code snippet below. On its entry of `approve()`, there is a requirement, i.e., `require(!((_value != 0) && (allowed[msg.sender][_spender] != 0)))`. This specific requirement essentially indicates the need of reducing the allowance to 0 first (by calling `approve(_spender, 0)`) if it is not, and then calling a second one to set the proper allowance. This requirement is in place to mitigate the known `approve()/transferFrom()` race condition (https://github.com/ethereum/EIPs/issues/20#issuecomment-263524729).

```
194     /**
195     * @dev Approve the passed address to spend the specified amount of tokens on behalf
            of msg.sender.
196     * @param _spender The address which will spend the funds.
197     * @param _value The amount of tokens to be spent.
198     */
199     function approve(address _spender, uint _value) public onlyPayloadSize(2 * 32) {

201         // To change the approve amount you first have to reduce the addresses`
202         //  allowance to zero by calling `approve(_spender, 0)` if it is not
203         //  already 0 to mitigate the race condition described here:
204         //  https://github.com/ethereum/EIPs/issues/20#issuecomment-263524729
205         require(!((_value != 0) && (allowed[msg.sender][_spender] != 0)));
```

```
207         allowed[msg.sender][_spender] = _value;
208         Approval(msg.sender, _spender, _value);
209     }
```

Listing 3.1: USDT Token Contract

Because of that, a normal call to `approve()` with a currently non-zero allowance may fail. In the following, we use the `Vault::setFairLaunchPoolId()` routine as an example. This routine is designed to approve the `FairLaunch` contract to move `debtToken` on users' behalf. To accommodate the specific idiosyncrasy, for each `safeApprove()` (line 460), there is a need to `safeApprove()` twice: the first one reduces the allowance to 0; and the second one sets the new allowance.

```
459   function setFairLaunchPoolId(uint256 _poolId) external onlyOwner {
460     SafeToken.safeApprove(debtToken, config.getFairLaunchAddr(), uint256(-1));
461     fairLaunchPoolId = _poolId;
462   }
```

Listing 3.2: `Vault::setFairLaunchPoolId()`

**Recommendation** Accommodate the above-mentioned idiosyncrasy about ERC20-related `approve()`/`transfer()`/`transferFrom()`.

**Status** This issue has been resolved as the supported `debtToken` has an implementation that is fully compliant with the ERC20 standard. With that, there is no need to adjust the current implementation.

## 3.2 Improved Precision By Multiplication And Division Reordering

- ID: PVE-002
- Severity: Low
- Likelihood: Medium
- Impact: Low
- Target: `WorkerConfig`
- Category: Numeric Errors [4]
- CWE subcategory: CWE-190 [2]

### Description

`SafeMath` is a widely-used Solidity `math` library that is designed to support safe `math` operations by preventing common overflow or underflow issues when working with `uint256` operands. While it indeed blocks common overflow or underflow issues, the lack of `float` support in `Solidity` may introduce another subtle, but troublesome issue: precision loss. In this section, we examine one

possible precision loss source that stems from the different orders when both multiplication (`mul`) and division (`div`) are involved.

In particular, we use the `WorkerConfig::isStable()` as an example. This routine is used to measure the stability of the given worker and prevent it from being manipulated.

```
115  /// @dev Return whether the given worker is stable, presumably not under manipulation.
116  function isStable(address worker) public view override returns (bool) {
117    IPancakePair lp = IWorker(worker).lpToken();
118    address token0 = lp.token0();
119    address token1 = lp.token1();
120    // 1. Check that reserves and balances are consistent (within 1%)
121    (uint256 r0, uint256 r1, ) = lp.getReserves();
122    uint256 t0bal = token0.balanceOf(address(lp));
123    uint256 t1bal = token1.balanceOf(address(lp));
124    _isReserveConsistent(r0, r1, t0bal, t1bal);
125    // 2. Check that price is in the acceptable range
126    (uint256 price, uint256 lastUpdate) = oracle.getPrice(token0, token1);
127    require(lastUpdate >= now - 1 days, "WorkerConfig::isStable:: price too stale");
128    uint256 lpPrice = r1.mul(1e18).div(r0);
129    uint256 maxPriceDiff = workers[worker].maxPriceDiff;
130    require(lpPrice <= price.mul(maxPriceDiff).div(10000), "WorkerConfig::isStable::
         price too high");
131    require(lpPrice >= price.mul(10000).div(maxPriceDiff), "WorkerConfig::isStable::
         price too low");
132    // 3. Done
133    return true;
134  }
```

Listing 3.3: `WorkerConfig::isStable()`

We notice the comparison between the `lpPrice` and the external oracle price (lines 130 – 131) involves mixed multiplication and devision. For improved precision, it is better to calculate the multiplication before the division, i.e., `require(lpPrice.mul(10000)<= price.mul(maxPriceDiff))`, instead of current `require(lpPrice <= price.mul(maxPriceDiff).div(10000))` (line 130). Note that the resulting precision loss may be just a small number, but it plays a critical role when certain boundary conditions are met. And it is always the preferred choice if we can avoid the precision loss as much as possible.

**Recommendation** Revise the above calculations to better mitigate possible precision loss.

**Status** The issue has been fixed by this pull request: `109`.

# 4 Conclusion

In this audit, we have analyzed the design and implementation of the `Alpaca Finance Protocol`, which is a leveraged-yield farming protocol built on the `Binance Smart Chain`. With the new support of new `configuration` contracts and an updated `Vault`, the system makes it distinctive and valuable when compared with current yield farming offerings. The current code base is well organized and those identified issues are promptly confirmed and addressed.

Meanwhile, we need to emphasize that `Solidity`-based smart contracts as a whole are still in an early, but exciting stage of development. To improve this report, we greatly appreciate any constructive feedbacks or suggestions, on our methodology, audit findings, or potential gaps in scope/coverage.

# References

[1] MITRE. CWE-1126: Declaration of Variable with Unnecessarily Wide Scope. https://cwe.mitre.org/data/definitions/1126.html.

[2] MITRE. CWE-190: Integer Overflow or Wraparound. https://cwe.mitre.org/data/definitions/190.html.

[3] MITRE. CWE CATEGORY: Bad Coding Practices. https://cwe.mitre.org/data/definitions/1006.html.

[4] MITRE. CWE CATEGORY: Numeric Errors. https://cwe.mitre.org/data/definitions/189.html.

[5] MITRE. CWE VIEW: Development Concepts. https://cwe.mitre.org/data/definitions/699.html.

[6] OWASP. Risk Rating Methodology. https://www.owasp.org/index.php/OWASP_Risk_Rating_Methodology.

[7] PeckShield. PeckShield Inc. https://www.peckshield.com.